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THE RADIOSENSITIVENESS OF CELLS AND TISSUES AND SOME MEDICAL IMPLICATIONS[1]

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CASUAL reading of contemporary medical records bearing on the action of roentgen rays and radium often gives the impression that little of such action is known, in spite of the fact that substantial or conclusive experimental data are available to indicate or to clearly establish the nature of such action. In some cases indeed the experimental indications are absolute. In other cases the experimental evidence may be inadequate, but the clinical data may be sufficient to suggest the probable effect of irradiation. It is true that many problems relating to radiotherapy are still the subject of controversy and that the large number of experiments which have been made has yielded only partial answers to many questions. Nevertheless, the facts already brought to light are sufficiently numerous to provide an imposing, although admittedly incomplete, scientific background. Unfortunately, the evidence furnished by experiments on animals and clinical observation has never been analyzed and correlated, and much of it has been lying on library shelves, buried in medical or other journals which are seldom read. Even among medical radiologists knowledge of the experimental background is not widely diffused.

The law based on the extensive investigations of Bergonié and Tribondeau (1904–1907), according to which young or immature cells are more radiosensitive than old or adult cells, has been generally recognized and has long been regarded as the essential foundation of radiotherapy. Numerous experiments have shown that direct irradiation of the pregnant uterus or of the young soon after birth causes retardation of growth of the skeleton and of various organs, including the brain. The degree of such effect varies with

[1] Abridged form, as read before the summer meeting of the American Association for the Advancement of Science, Pasadena, California, June 15 to 20, 1931.

the dose, the age of the animal and the natural life cycle of the species. The cells and tissues of a given species rapidly become less sensitive as the animal emerges from the early phase of its existence, during which growth is a prominent feature. Indubitable as is the relation of the age of cells to radiosensitiveness, analysis of the experiments made to test the susceptibility of different organs and tissues brings out the even more important fact that each variety of cell in the body has a specific sensitiveness, or rather a specific range of sensitiveness, to radiation. This is not intended to imply that all cells of one kind, such as lymphocytes or squamous epithelial cells, react in precisely the same way to a given dose of rays. A certain measure of variation in reaction must necessarily occur, because different cells of the same kind are struck by the rays while in different stages of metabolism. Other still unknown factors also may play a part. However, if allowance be made for such variation, and if reaction time be taken as a criterion, the specific sensitiveness of each kind of cell looms up as the dominant single fact of radiology and deserves to be recognized as a law. And yet, if we may judge by present-day writings, the existence of such a law and of its medical and biological implications is not at all realized. For years much has been made of the dogma that pathologic cells are more radiosensitive than normal cells of the same kind, but, as Lazarus-Barlow and others have shown, the foundation on which this dogma rests is tenuous and insecure. The physiologic condition of cells undoubtedly has some influence on their sensitiveness, but, as I shall bring out presently, such influence is small as compared with the specific natural susceptibility of each variety of cell. Although the factors responsible for such specificity have not yet been determined, the sensitiveness peculiar to each kind of cell appears to be related chiefly to the natural life cycle. Thus the lymphocytes, whose metabolic cycle among human cells is the shortest, are also the most radiosensitive, and the nerve cells, whose life cycle is the longest, are also the most resistant to irradiation. But to this question as to many others the final answer has not been given.

When a living tissue or organ is exposed to roentgen rays or radium, a more or less important proportion of cells may subsequently exhibit temporary inhibition of metabolic activity or complete and permanent disintegration, or may not show any deleterious effect. Moreover, if the time intervening between irradiation and perceptible reaction is taken as a criterion, it will be found that certain species of cells react more rapidly than others to a given dose, or the degree of reaction to the same dose is greater for some kinds of cells than for others. According to our present knowledge cells may be classified, according to their radiosensitiveness, in the following order:

Lymphoid cells (lymphocytes).
Polymorphonuclear and eosinophile leukocytes.
Epithelial cells:
(1) basal epithelium of certain secretory glands, especially the salivary glands;
(2) basal epithelium (spermatogonial cells) of the testis and follicular epithelium of the ovary;
(3) basal epithelium of the skin, mucous membranes, and of certain organs, such as the stomach and small intestine;
(4) alveolar epithelium of the lungs and epithelium of the bile ducts (liver), and
(5) epithelium of tubules of the kidneys.
Endothelial cells of blood vessels, pleura and peritoneum.
Connective tissue cells.
Muscle cells.
Bone cells.
Nerve cells.

Although the difference in susceptibility between the most sensitive and the least sensitive varieties of cells is considerable, none of the cells is wholly invulnerable to radiation; all cells, whatever their variety, may be destroyed or injured if exposed to a sufficiently large dose of rays, especially if doses within the therapeutic range are disregarded.

Radiosensitiveness of Different Species of Cells

Lymphoid cells: Of the different kinds of cells which make up the tissues and organs of the body, the most susceptible by far are the lymphocytes. This important fact was brought to light by the early and extensive experiments of Heineke (1903, 1904, 1905) and has since been fully confirmed by the subsequent investigations of Warthin (1906), Krause and Ziegler (1906–1907), and Fromme (1917), Hartmann (1920), Jolly (1924), Tsuzuki (1926), Piepenborn (1929) and others. When the entire body of different species of animals was exposed to roentgen rays, Heineke found that most of the tissues and organs remained unaffected, but that the spleen, lymph nodes, intestinal lymph follicles, circulating blood, bone-marrow and all agglomerations of lymphoid cells showed a more or less pronounced destruction of lymphocytes. The degree of such destruction was proportional to the dose of rays and varied with the interval between irradiation and death. In the spleen, lymph nodes and other lymphoid structures the destruction of lymphocytes started around the germinal center and gradually extended toward the periphery of the follicles. As the number of intact lymphocytes diminished the stroma became prominent, and often this feature was so pronounced that the follicles could be recognized only

by the blood vessels and the concentric arrangement of the stroma. Heineke observed such destruction of lymphocytes as early as two hours after irradiation. The extent and duration of this destructive phase depended on the intensity of irradiation, continued for several days, and was accompanied by a progressive reduction in volume or atrophy of the affected structures.

As described by Heineke, such destruction is characterized by disorganization and fragmentation of the nuclear chromatin, scattering of the fragments of chromatin between the remaining intact cells and in the reticular spaces, where the fragments gather into clumps or balls. Then the clumps or balls of degenerate chromatin are gradually taken up by some of the reticular cells which assume a phagocytic property and swell as the amount of ingested chromatin débris increases. The disposal of chromatin material from the destroyed cells continues until all such material has undergone phagocytosis. The nuclear débris ingested by the phagocytes apparently undergoes intracellular digestion, because the number and size of the ingested fragments diminish steadily. Some hours later, the phagocytic reticular cells themselves begin to disappear. After a single massive irradiation or repeated moderate doses, all the lymphocytes may be destroyed, but after a single small or moderate dose, a certain proportion of the cells appear to resist the action of the rays. From one to three weeks after exposure, if the irradiation has not been sufficiently intense to destroy all the lymphocytes, more or less regeneration of the lymphoid tissue may be observed and complete cellular restoration may occur. Two or three days after exposure to roentgen rays, degenerative alteration of other cells, notably the polymorphonuclear leukocytes and eosinophiles, also becomes perceptible, and many of these cells disappear from the splenic pulp and bone marrow.

Warthin's description of the effect of roentgen rays on the lymphoid structures corroborates the observations of Heineke in every particular, except that, by examining the tissues soon after irradiation, Warthin found unmistakable evidence of the disintegration of lymphocytes within fifteen minutes after exposure of the animals to the rays, and the cellular degeneration continued for several days. Similar effects were obtained with radium by London (1903), Heineke (1904), London (1905), Thies (1905) and Lazarus-Barlow (1922). Rudberg (1907), Aubertin and Bordet (1909), Arella (1910), Regaud and Crémieu (1912) and others have likewise shown that roentgen rays and radium exert precisely the same influence on the small round cells of the thymus gland, and their work strongly supports Hammar's conclusion that the small cells of the thymus gland are indeed lymphocytes. Others, notably Senn (1903), Heineke (1903, 1905), Guilloz and Spillmann (1904), Aubertin and Beaujard (1904, 1905, 1908), Brown (1904), Bryant and Crane (1904), Capps and Smith (1904), Helber and Linser (1905), Benjamin, von Reuss, Sluka and Schwarz (1906), Aubertin and Delamarre (1908), Taylor, Witherbee and Murphy (1919), Russ (1919, 1921) and Leitch (1921), have proved conclusively that the lymphocytes in the circulating blood are equally sensitive to irradiation and also destroyed in large numbers by exposure to roentgen rays or radium.

Epithelium of the salivary glands: Next to the lymphocytes in point of radiosensitiveness are the basal epithelial cells of the salivary glands. Actually these cells are more sensitive to radiation than the polymorphonuclear and eosinophilic leukocytes. This is evidenced by the fact that, whereas microscopically perceptible changes in the two latter varieties of cells can seldom be found within the first six hours after exposure to the rays, clinical signs of salivary reaction can usually be observed in from three to six hours after irradiation. These signs consist in swelling, redness, and tenderness in the region of the irradiated glands and, when bilateral, may stimulate the salivary phase of mumps. If all the glands on both sides have been exposed to the rays, the foregoing clinical signs may be rapidly followed by decrease in salivary secretion, often leading to dryness of the mouth lasting from a few days to two or more weeks. Such reaction of the salivary glands is characterized by mucoid degeneration of the basal epithelium. The cells swell, the excretory ducts become occluded, and the secretion accumulates within the glands; hence swelling and tenderness of the glands, and dryness of the mouth. Following a single irradiation salivary reaction is always transient; after a time, usually from twenty-four to seventy-two hours, the acute phase of the reaction subsides and the clinical signs gradually abate. Following repeated irradiation, however, the secretory function of the glands may cease and dryness of the mouth may persist for a long time. Such effects occur only when the glands on both sides have been exposed to the direct action of the rays. Salivary reaction does not occur when other parts of the body are irradiated, and exposure of the glands on one side causes a reaction on that side only. When the reaction is unilateral, dryness of the mouth is seldom noticed, undoubtedly because the glands on the opposite side furnish a sufficient quantity of saliva to lubricate the oral mucosa. The experiments of Lazarus-Barlow (1922) and of Mottram (1923) indicate that epithelial cells which produce mucus are much more sensitive to irradiation than other epithelial cells. The first effect is mucoid degeneration

with excessive and abnormal production of mucus, followed by arrest of mucus formation. This has been shown to occur in the intestine, and the behavior of the salivary glands under irradiation make it seem likely that the mucus-producing cells in the epithelial lining of these glands are similarly affected by the rays.

Epithelium of the testis and ovary: The testis is not so sensitive as some of the leukocytes or the salivary glands, but with the exception of these is the most sensitive structure in the body. The radiosensitiveness of the organ is due to susceptibility of the spermatogonial cells, which are affected deleteriously even by a moderate dose of roentgen rays. The cells of Sertoli are relatively resistant to irradiation, and this fact tends to support the view that they supply nourishment to the basal layer of seminal cells, the spermatogonia. The spermatocytes of the first and second order, as well as the spermatids and mature spermatozoa, are distinctly less sensitive than the spermatogonia and are affected only by larger doses. Even so, much of the cellular degeneration is probably secondary to the direct action of the rays on the basal cells. After a sufficiently large dose, degeneration of spermatogonia proceeds to complete disintegration. This is accompanied by failure of the cells to evolve into spermatocytes and mature spermatozoa, and the final result is permanent azoospermia. After a dose insufficient to cause permanent azoospermia, a certain proportion of the spermatogonia may be able to survive and serve as a nucleus for histologic regeneration and functional restoration. Large doses repeated at comparatively short intervals are almost certain to induce permanent castration. The interstitial tissue, on the other hand, is much more resistant and is not perceptibly influenced by ordinary therapeutic irradiation.

The radiosensitiveness of the ovary is essentially the same as that of the testis, and the cells to which the specific susceptibility of the gland is due are the ova and the epithelium of the follicles. The sensitiveness of different follicles varies according to the stage of development. Depending on the dose of rays to which the ovary has been exposed or to the number of times a given dose has been repeated, the effect of irradiation may be disintegration and disappearance of a certain proportion of the follicles or complete and permanent destruction of every follicular structure. A certain proportion of the primordial follicles may escape if the dose has been small. Moreover, the steps in the reaction of the follicles are analogous to those of spontaneous physiologic atresia.

Epithelium of the skin, mucous membranes and gastro-intestinal tract: The skin can tolerate with impunity a considerable single dose of roentgen rays, but when the limit of tolerance is exceeded it may undergo a series of reactive changes. The first clinical manifestation of excessive irradiation is a readiness of the hair to fall out in the exposed territory. After a still larger dose, not only does epilation occur, but varying degrees of reactive inflammation of the skin may take place. Dermatitis may appear as a slight erythema lasting a few days and followed by pigmentation corresponding to the exposed area; as a more pronounced, bright red erythema with a sensation of heat, followed by the formation of vesicles and later by itching, exfoliation of the epidermis and deep pigmentation; or, in extreme cases, as an intense, painful erythema, with or without fever, and followed by more or less extensive ulceration of the entire thickness of the skin. Mild radiodermatitis may not leave any permanent marks beyond slight atrophy of the irradiated area of skin, provided the inflammatory reaction results from a single exposure. When such reaction appears after the same area of skin had been exposed several times, it is likely to be followed, from one to three years later, by telangiectasis. The sudoriferous and sebaceous glands of the irradiated skin also undergo degenerative changes. Radiodermatitis accompanied by the formation of vesicles is followed by more extensive desquamation or by the actual formation of small, rounded or large, irregular cutaneous scars. When severe radiodermatitis is followed by ulceration, the ulcers are slow to heal. This is due partly to the peculiar character of injury produced by irradiation and partly to secondary infection which so commonly complicates the ulceration.

The sensitiveness of the epithelium of mucous membranes is much the same as that of the skin. Excessive single irradiation causes first anesthesia, then dryness, redness from hyperemia and edema. Depending on the dose, these clinical manifestations may abate and disappear or may be followed by ulceration. The radiosensitiveness of specialized mucous membranes, such as the mucosa of the stomach and intestine varies with each structure. Irradiation of the stomach causes temporary reduction in the secretion of gastric juice, and this affects the production of hydrochloric acid and pepsin. If the stomach is exposed repeatedly at relatively short intervals, the gastric acidity and pepsin fall lower and lower, and this may continue for weeks or months. If the exposures were repeated indefinitely the secretory activity of the gastric mucosa might be completely and permanently arrested. The susceptibility of the intestine varies in its different parts. The mucosa of the colon is relatively insensitive to the action of the rays; at least, it is much less sensitive than that of the small intestine. The most sensitive portion of the

mucosa of the digestive tract is that of the duodenum and jejunum, which may be irritated by doses insufficient to disturb the overlying skin. When the upper half of the abdomen is exposed to a therapeutic dose of roentgen rays, anorexia, nausea and vomiting often follow within a few hours, and diarrhea may appear several days later. Exposure to excessive doses, such as have been employed in many experiments on animals, causes mucoid degeneration of the intestinal epithelium, hyperemia, edema of the mucosa and submucosa, and such changes may be followed by desquamation of the epithelium. According to the severity of reaction, the epithelium may regenerate or the breach in the mucosa may be repaired by connective tissue.

Epithelium of the lungs, liver and kidneys: The lungs, liver and kidneys are only moderately sensitive to irradiation. Grossly excessive doses may cause cellular degeneration and reactive inflammation, and the injury may be repaired by connective tissue, which may lead to slight or pronounced impairment of function.

Endothelium: The radiosensitiveness of the endothelium of blood vessels, pleura and peritoneum is approximately the same as that of the skin. The effect of excessive irradiation is swelling of the endothelial cells, which degenerate and desquamate into the lumen of the vessel. The media also may swell. As the acute reaction subsides the cellular injury may be repaired by hyperplasia of adjacent cells or the entire wall of the vessel may thicken, and the lumen may be narrowed or completely obliterated.

Connective tissue, muscle, bone and nerve tissue: The sensitiveness of these different tissues decreases in the order named. Bone and nerve cells are the most resistant of all cells, but it must not be inferred that they are wholly insensitive to irradiation. A sufficient dose of roentgen rays or radium can readily retard the development of bone in a young rapidly growing animal, and even the mature bones of adult animals may be devitalized. Nerve cells can tolerate comparatively large doses without giving perceptible evidence of direct injury. The cellular changes in nerve tissue observed after irradiation appear to be indirect and secondary to action of the rays on more sensitive elements, such as the endothelium of the blood vessels which supply the nerve tissue.

Stimulating effect of irradiation: For years the legend that roentgen rays or radium, under certain conditions of dosage, may increase the growth and metabolism of cells has gained wide circulation. This notion has arisen from the attempt to apply to these agents the so-called Arnt-Schulz law, according to which small doses stimulate and large doses depress cellular metabolism. Based on pharmacologic grounds, this doctrine has not been generally accepted, even by pharmacologists. The attempt to apply it to the action of roentgen rays is unwarranted, because the experimental evidence on which it is based is extremely meager and apparently invalid. That a measure of acceleration in cellular metabolism may occur under certain conditions has been shown repeatedly both in animals and plants, but such unusual acceleration is a transient phase of reaction and is invariably followed by more or less pronounced inhibition of function and cellular degeneration. Another factor in the propagation of this notion of a stimulating action of the rays has been the regression of pathologic lesions after exposure to small doses of roentgen rays. Such regression is best explained by the exceptional radiosensitiveness of certain varieties of cells. As the result of primary degeneration of certain cells a secondary and indirect stimulation may sometimes be observed. Such is the increase in connective tissue cells in certain tissues and organs after repeated irradiation; the connective tissue is laid down to replace other cells which the rays have caused to undergo degeneration. Any primary or direct acceleration of cellular metabolism must be regarded as an effort of the cell to counteract or compensate for the noxious influence of the rays; in other words, it is purely a defense reaction. Continued acceleration of metabolism can not be induced by roentgen rays or radium, which always cause degenerative changes or have no effect whatever. Irradiation of certain tissues, such as the skin, repeated over a long period of time may cause hyperplasia of the epithelium, and this in turn may lead to malignant transformation. This is not stimulation in the sense here employed, but the alteration of a normal to an aberrant function due to chronic irritation.

Comparative influence of rays of different wave-length: Roentgen rays and radium have the same general effect on living tissue. Such variations as may be observed can be accounted for by difference in the methods of irradiation with each agent. Unfiltered radium buried in the substance of a tissue produces an intense destruction of cells immediately adjacent to the radioactive unit. The degree and extent of destruction can be modified at will by filtration. The conditions under which roentgen rays are generated prevent anything but external irradiation. If the effect of external irradiation with radium is compared with that of similar irradiation with roentgen rays, any variation attributable to difference in wave-length will be small; the greater part of the difference must be charged to variation in the total quantitative dose of each kind of energy. Quality of radiation plays a definite part in the effect, but this part is much smaller than the part played by quantity of radia-

tion. To illustrate this further, I need only draw your attention to the difference of action between unfiltered roentgen rays of relatively long wave-length and rays of short wave-length generated at voltages of 80 and 200 peak kilovolts, respectively. A dose of the former beyond the tolerance of the skin to an area more than one inch in diameter is likely to result in ulceration, whereas a corresponding dose of rays of short wave-length seldom causes ulceration, but usually induces a dense brawny induration of the skin and subcutaneous tissues and adhesion of the underlying muscles.

OUTSTANDING MEDICAL IMPLICATIONS

To attempt to deal adequately with this phase of my subject would be to risk overtaxing your patience. I shall confine myself, therefore, to a brief outline of the more important medical relationships.

Radiotherapy for inflammatory conditions: Knowledge of the specific sensitiveness of different species of cells to roentgen rays or radium is of fundamental importance in the treatment of inflammatory lesions as well as in the diagnosis and treatment of certain neoplastic processes. It has long been known that many acute or chronic, suppurative or non-suppurative, inflammations are favorably influenced by roentgen rays or radium. In some of these conditions indeed irradiation has been found to be the therapeutic method of choice. Among the acute inflammations amenable to such treatment may be mentioned furuncle, carbuncle, lymphadenitis, pneumonia in certain stages, parotitis and erysipelas. The more acute the process the more quickly it responds to irradiation and the smaller the dose required. Exposure of such lesions at an early stage (phase of leukocytic infiltration) usually causes them to undergo rapid resolution. Irradiation at a slightly later stage (phase of beginning suppuration) hastens the suppurative process. In both cases, but especially in the former, the course of the inflammation is shortened and pain is quickly allayed. Usually, a single exposure to the rays is sufficient. Tuberculous lymphadenitis, tuberculosis of the cornea and iris, trachoma, actinomycosis, and many diseases of the skin may be cited as examples of chronic inflammation amenable to radiotherapy. In such conditions, however, treatment must be repeated at intervals for some time. The rate and mode of reaction of inflammatory lesions indicate that the rays act chiefly by destroying the infiltrating lymphocytes, the exceptional sensitiveness of which has already been pointed out. The rate of reaction of acute inflammations corresponds so closely to the rate at which normal lymphocytes are known to be destroyed by the rays that, even in the absence of other evidence, the analogy can not be regarded as a coincidence. Moreover, confirmatory evidence has been provided by frequent microscopic observation, in irradiated lesions of this kind, of lymphocytic destruction in every respect similar to that which was first observed and described by Heineke.

Leukocytic, and especially lymphocytic, infiltration is an early and prominent feature of most inflammatory conditions. Especially is this true in inflammations caused by bacterial infection. If it can be assumed that the leukocytes, which the organism mobilizes around the site of infection, represent an effort to localize the infection and get rid of the infectious material by phagocytosis or otherwise, it must be inferred that the infiltrating cells contain or elaborate within themselves the protective substances which enable them to neutralize the bacterial or other toxic products which give rise to the defensive inflammation. If these assumptions are well founded, it seems not unreasonable to deduce that irradiation, by destroying the infiltrating lymphocytes, causes the protective substances contained by such cells to be liberated and thus be made even more readily available for defensive purposes than they were in the intact cells. All the circumstances surrounding the behavior of inflammatory lesions after irradiation are in harmony with this view. The same process also undoubtedly plays an important part in the reaction of chronic inflammatory lesions, but in such cases the reaction is modified according to the degree of leukocytic infiltration on the one hand and to the amount of connective tissue on the other. This probably explains why the resolution and cure of chronic inflammations, such as those mentioned, require that irradiation be repeated at intervals for some time.

Radiotherapy of the genital glands: The radiosensitiveness of the genital glands is important from more than one point of view. The relative ease with which testicular or ovarian function can be abolished by irradiation furnishes a simple method of accomplishing this result whenever functional arrest is necessary or desirable. The method has seldom been applied to the male, but it is commonly employed in the female as an increasingly valuable method of treating hemorrhagic disturbances and fibromyoma of the uterus. Functional arrest of the ovaries indirectly causes atrophy of the uterus and of the fibroid tumors. Both in the male and female, roentgen rays or radium might well be utilized to castrate the feebleminded, a method which would remove the objection to surgical operation. The danger of sterilization to professional radiologists and non-professional technical assistants has long been realized. Fortunately, modern methods of protection, if applied, remove all danger from such employment.

Radiotherapy for benign and malignant tumors: The specific sensitiveness of different kinds of cells constitutes the most important single factor in the treatment of neoplasms. The value of roentgen rays or radium in different varieties of tumor depends mainly on this feature. The susceptibility of tumors to irradiation agrees closely with the radiosensitiveness of normal cells of the same kind as those from which the tumors are derived and of which they are largely composed. Thus, the inordinate hyperplasia of lymphoid structures which characterizes Hodgkin's disease, lymphosarcoma, and lymphatic leukemia retrogresses under irradiation at the same rate as normal lymphocytes are known to be destroyed by similar exposure. In fact, so striking is the parallel that irradiation is now being used daily as a means of distinguishing such conditions when their clinical features do not permit absolute identification. In some cases, indeed, the radiotherapeutic method of diagnosis is more accurate and dependable than microscopic examination.

The only tumor which approaches lymphoblastoma in susceptibility to irradiation is the embryonal carcinoma, or seminoma, of the testis, the radiosensitiveness of which corresponds to that of normal spermatogonial cells. This is the most common neoplasm affecting the organ and heretofore has often been mistakenly regarded as a va[illegible] of sarcoma. Primary and secondary growths c[illegible]d retrogress rapidly and some disappear compl[illegible] after irradiation. The reaction of mixed, or teratoid, tumors of the testis is less rapid and seems to vary with the proportion of spermatogonial epithelium entering into their structure.

Knowledge of the relative radi[illegible]veness of different cells has enabled Ewing a[illegible]others to distinguish a group of bone tumors from other neoplasms which affect the skeleton. Ewing has designated this tumor as endothelial myeloma, because endothelial cells are a prominent feature. Among the malignant tumors of bone they are the most sensitive to irradiation. In fact, the other malignant growths which attack bone can hardly be said to have any sensitiveness; rather they are noteworthy for their resistance. Endothelial myeloma, on the contrary, is distinctly sensitive, and large tumors of this kind melt away with astonishing rapidity. The only other bone tumor which is radiosensitive is the usually benign giant-cell tumor, but its reaction to irradiation is unlike that of any malignant neoplasm. Instead of being followed by rapid or slow, but steady regression, irradiation of such growths causes them to swell and become tender. The patient and the uninitiated physician may naturally conclude that exposure to the rays has stimulated the tumor to increased growth, and the limb may be unnecessarily sacrificed. Such inflammatory reaction is a transient phase which lasts two or three weeks and is followed by slow regression and repair of the tumor by deposition of new bone. This characteristic reaction of giant-cell tumor constitutes at once a valuable means of identification and treatment and furnishes additional evidence that tumors of this kind, at least at the outset, are not true neoplasms but chronic inflammatory lesions.

Many other examples might be mentioned, but the foregoing are sufficient to illustrate the important bearing on medical diagnosis and treatment of the radiosensitiveness of cells and tissues. Heretofore, for some reason, biologists have seldom made use of radiation for experimental purposes. As soon as they begin to realize its possibilities, they will find in the method a means of acquiring much valuable information, and such increase in knowledge will help to extend the diagnostic and therapeutic applications.

OBITUARY

JAMES WILLIAM TOUMEY

JAMES WILLIAM TOUMEY, D.Sc., D.For., professor of silviculture at the Yale School of Forestry, died at his home in New Haven on May 6, 1932. He was one of the pioneers and founders of American forestry. He was a great teacher and educator, a scientist of distinction, an author, and an influential leader in advancing the movement of forestry. He had been associated with the Yale School of Forestry from the time of its establishment in 1900. His part in building the school, in setting and maintaining high educational standards, and making the institution a force in the development of forestry in the nation can not be measured.

Trained as a botanist, he brought his extensive knowledge of plant science to bear on the problems of forestry. By his own study and experience he mastered the technical aspects of forestry and made a large contribution to the application of forestry principles to American conditions. His power as a teacher lay in his unflagging enthusiasm, in his personal interest in students and sympathetic understanding of their needs, and in his ability to stimulate individual effort on their part. He possessed high qualities as a scientific investigator, keen perception, unusual sense of values, originality and ingenuity in research, and persistence in carrying his studies to a conclusion. He had unfaltering faith in the work he

was doing and in the value and necessity of forestry in our national life. He was ever optimistic and courageous in the face of obstacles and he possessed a spirit of devotion that won a following in all his enterprises.

While intense in the application of his efforts to teaching and research in his special field, his general interests were broad, as exemplified in his reading, his university associations, and his participation in public affairs. He was simple and straightforward in thought and in his dealing with men. He was tolerant of the opinions of others, but he swiftly detected pretense, sophistry and self-seeking. His general personality and kindliness won the affectionate regard of his students and made a host of other friends.

Professor Toumey was born in Lawrence, Michigan, on April 17, 1865. His youth was spent on the farm of his father, Dennis Toumey, and his early educational work was in the local schools. He prepared for college at the Decatur High School, but taught school for several years before entering the Michigan State Agricultural College, from which he graduated in 1889. In college he directed his chief efforts to the study of botany. His work was given recognition by an appointment as an instructor in the college in 1890, and by the degree of Master of Science in 1893.

In 1891 he was called to the University of Arizona where he remained until 1898, advancing by steps to a full professorship in botany. At the same time he held the position of botanist in the State Agricultural Experiment Station, under whose auspices he conducted his scientific research. He served as the acting director of the station in 1897–1898. During this period Professor Toumey made very distinctive contributions to plant science. He conducted investigations in the fields of taxonomy, ecology, physiology and pathology, and also in entomology. He did special work on the date palm and became widely recognized as an authority on cacti. He established a cactus garden at Tucson which has been continued by his successors. He built up a large cactus herbarium, drawing upon it to aid the plant collections of Kew and other institutions. In 1897 he visited England and personally assisted in the systematic arrangement of the collection at Kew. About twenty-five articles and bulletins remain as a record of his investigative work in Arizona.

Professor Toumey began his formal work in forestry in 1899 when he was appointed superintendent of tree planting in the Division of Forestry, U. S. Department of Agriculture. He was selected for the post because of his knowledge of trees and in recognition of the experimental work which he had already done in tree planting. His duties were to encourage reforestation and to cooperate with private owners. He traveled extensively, studying local problems in various regions and assisting individuals by direct advice and through numerous publications.

When the Yale Forest School was established in 1900 Professor Toumey was chosen as one of the two regular members of the staff. Forestry was new and untried in this country, and there was little instructional material applicable to American conditions. It was a period of building the first foundations both of forest education and of the science and practice of American forestry. In this work Yale played a prominent part and Professor Toumey's contribution was large.

When the dean of the school, Henry S. Graves, was called to Washington to take charge of the U. S. Forest Service in 1910, Professor Toumey succeeded him as head of the school, a post which he held until 1922. During this period he materially enlarged the endowments and the physical facilities of the school. He was responsible for the gift of the new central building, Sage Hall. He enlarged the forest properties of the institution and secured large accessions to the library. He himself donated a collection of some 2,500 specimens to the forest herbarium. Even more important, he developed and strengthened the educational work, adhering to high scholastic standards and ideals as essential in a professional preparation for forestry.

In 1922 he retired from the deanship and devoted his efforts to teaching and research. The last decade of his life was the richest in his personal contributions to the science of forestry. Many research projects which he had previously initiated were brought to fruition.

He directed his chief efforts to the study of forest tree seeds and seedlings, to the environmental factors affecting the life of seedlings, trees and stands, and to the application of the principles of silviculture in intensive practice. He developed the property owned by the school at Keene, New Hampshire, as an experimental and demonstration forest of first importance. He secured funds for additional land, bringing its area to about 1,500 acres or about two thirds of its projected size. During recent years he made the Yale Forest at Keene a center of his silvical studies and his practical experiments in silviculture, and on it conducted a summer camp, with a selected group of graduate students. Before his last illness he was able to complete a report describing the forest, the history of the operations upon it, and the practical results of management. The Keene Forest will always stand as a memorial of his work in forestry.

Professor Toumey contributed extensively to the literature of forestry. His "Seeding and Planting" and "Foundations of Silviculture" are standard works

widely used as text and reference books by students in the forest schools and by others interested in forestry.[1] He was responsible for initiating at the School of Forestry a series of scientific bulletins, now comprising thirty-three numbers. Of these he was author or co-author of eight, and seven others were written by graduate students working under his direction. In addition he wrote extensively for the forestry journals and other periodicals. His bibliography covers a wide range of subjects, including articles of a scientific character, discussions of applied silviculture, forest taxation, watershed protection, forest economics and public forest policy.

Professor Toumey was called upon frequently for public addresses and for participation in public enterprises through committees and advisory boards or as an officer in technical and civic associations. In 1929 he was a member of the American delegation to the International Congress of Forest Experiment Stations at Stockholm, Sweden. He was granted the honorary degree of Doctor of Science by Syracuse University in 1920 and the honorary degree of Doctor of Forestry by the Michigan State College in 1927. He was a fellow of the Society of American Foresters, and a member of Sigma Xi, and of a large number of organizations engaged in advancing the interests of forestry and conservation.

In 1897 Professor Toumey married Miss Constantia Blake, of New Haven, who died in 1904, leaving a son, James W. Toumey, now a surgeon in New York. His second marriage was to Miss Nannie Trowbridge, of New Haven, in 1908.

His ashes will be taken to the Keene Forest, to which he was deeply devoted and which will be an appropriate sanctuary for his last resting place.

HENRY S. GRAVES

SCHOOL OF FORESTRY,
YALE UNIVERSITY

[1] *Seeding and Planting.* James William Toumey. John Wiley and Sons, New York, 1916. Revised by J. W. Toumey and C. F. Korstian, 1931.
Foundations of Silviculture. James William Toumey. John Wiley and Sons, New York, 1928.

SCIENTIFIC EVENTS

BRITISH SOLAR ECLIPSE EXPEDITION TO CANADA

ACCORDING to the astronomical correspondent of the London *Times*, preparations are well advanced for the observation of the total eclipse of the sun on August 31 by an expedition from the Royal Observatory, Greenwich. The eclipse will be visible only from North America and limited regions surrounding that continent, the path from which the sun will be seen totally eclipsed crossing Hudson's Bay, Quebec Province, and the northeastern states, where totality will last about 100 sec. The observers, Dr. John Jackson and Mr. C. R. Davidson, F.R.S., of the Royal Observatory staff, will proceed to a selected station near the town of Parent, in the Province of Quebec, on the Canadian National Railway, to observe the eclipse.

There is to be no attempt to solve the problem of the bending of light-rays as they pass the sun that has formed part of the program on the occasion of some recent eclipses, but the equipment is chosen for making photographic records of the corona that is seen surrounding the sun only during total eclipses, and of its spectrum and of that of the chromosphere or solar atmosphere for which these occasions are specially suitable. Photographs of the corona will be taken with a telescope that has an object-glass 6 inches in diameter and of 45 feet focal length, giving therefore an image of the sun 5 inches in diameter. This will be placed in a fixed horizontal position and fed by a rotating coelostat.

The spectra of the corona and of the chromosphere will be photographed with a telescope with object glass 7 inches in diameter, of 21 feet focal length, producing, therefore, an image of the sun 2.3 inches in diameter. The spectrum will be formed by a prism, whose effective angle is 45 degrees, placed before the object glass. Such photographs result in a series of parallel arcs, which are actually pictures of the edge of the sun formed by light of different wavelengths. It is hoped that these will enable a connection to be traced between the chromosphere and the corona, and a differentiation to be made between the individual rings, or layers, which it is believed make up these solar surroundings.

Apparatus is also being taken with which to photograph the spectrum of the chromosphere and of the corona in its red and infra-red region. This is a grating slit spectrograph, the sun's image being formed on the slit by a mirror 9 inches in diameter and of 10 feet focal length. Another spectrograph of a different type, the spectrum in this case being produced by a prism with refracting angle of 30 degrees, will be used to photograph certain groups of lines due to calcium, and then deduce their absolute relative intensities at different heights in the chromosphere. Use will be made of curved films in some of these operations to secure good definition over a considerable length of the spectrum and advantage will be taken of the new Ilford infra-red sensitive plates.

INVESTIGATION OF COSMIC RADIATION

ACCORDING to information from the Massachusetts Institute of Technology, it will participate this summer in the world-wide survey of cosmic radiation to

be undertaken under the auspices of the Carnegie Institution of Washington.

The project, which calls for the establishment of some 20 scientific stations on six continents and in every zone except the Antarctic, is under the direction of Dr. Arthur H. Compton, of the University of Chicago.

Dr. Ralph D. Bennett, associate professor of electrical measurements at the institute, with the cooperation of Dr. J. L. Dunham of Harvard University, will undertake cosmic radiation studies in Alaska, California and Colorado. Dr. Bennett made preliminary radiation studies in Colorado last year and since then he has developed a portable counting tube apparatus. It is planned to set up this instrument at high altitudes in the Rocky Mountains for measurements of the stopping power of different materials for the particles which actuate the counting tube. Dr. Bennett has left Cambridge to join his party in the west.

During the investigations measurements of cosmic radiation will be carried on continuously, day and night, over a long period, to determine whether there is a diurnal variation. The survey will also make it possible to compare directly intensities of radiation at many points. These studies are expected to show definitely whether cosmic radiation is associated with terrestrial locality.

Dr. Robert B. Brode, of the University of California, visiting professor of physics at the Institute of Technology, will cooperate with Dr. Bennett and Dr. Dunham in measurements in the California mountains. In Colorado the party will have the assistance of Professor J. C. Stearns, of the University of Denver. Professor M. S. Vallarta, of the department of physics, will join the party of Professor Compton when it begins its investigations in the highlands of Mexico. Dr. Compton's party will also make measurements in Hawaii, Australia, New Zealand, Peru, the Canal Zone and in northern Canada in the vicinity of the north magnetic pole.

The Asiatic survey will be directed by Professor J. M. Benade, of Lahore, who will make investigations in Ceylon, Java and northern India. South African observations will be made by Professor S. M. Naude, of the University of Cape Town. Dr. E. O. Wollan, of the University of Chicago, will go to Spitzbergen and other European points. Dr. Allen Carpe, of New York, lost his life recently in the beginning of the cosmic radiation survey at the head of the Muldrow Glacier on Mt. McKinley in Alaska.

CONFERENCE OF THE INTERNATIONAL STANDARDS ASSOCIATION

ENGINEERS of eighteen nations met in Milan, Italy, on May 30 to open a series of technical conferences aimed to secure international uniformity in standards for airplane and automobile parts, cutting tools, iron and steel, and other subjects.

The conferences, to extend through the ninth of June, are under the auspices of the International Standards Association, which includes in its membership the national standardizing bodies of the United States, France, Germany, Italy and 14 other nations.

Ernest Wooler, chief engineer of the Timken Roller Bearing Company of Canton, Ohio, an American delegate, will discuss before the conference on ball and roller bearings the American proposal to replace the thousand different types and sizes now manufactured in the United States alone.

Subjects which will be studied by the conference on aeronautics in an effort to secure greater international uniformity in essential features of airplanes, are: direction of rotation of the engine, safety belts, propeller hubs, electric voltages aboard airplanes, floats for seaplanes, parts of the steering equipment and engine control levers, dimensions and arrangement of instruments, instrument dials, identification colors for pipe lines, screwed pipe connections and valves, screw threads and principles for the computation of rating of airplanes and engines.

Other conferences will be held on cutting tools, center heights and dimensions of shaft ends of electric motor and driven machines, shafting keys, fluid meters and sieves for testing purposes.

The countries which will be represented at the International Standards Association conferences through their national standardizing bodies are: Austria, Belgium, Czechoslovakia, Denmark, Finland, France, Germany, Holland, Hungary, Italy, Japan, Norway, Poland, Roumania, Russia, Sweden, Switzerland and the United States.

EXPERIMENTAL FORESTS ESTABLISHED IN MINNESOTA

THREE field laboratories, comprising a total of approximately 5,396 acres, have been set aside as experimental forest areas within the Chippewa and Superior National Forests in Minnesota by the U. S. Forest Service. These areas were chosen after a careful study as being representative of the various types and conditions found in the forested area of Northern Minnesota.

The Cutfoot Experimental Forest is located approximately twenty-four miles from Deer River and is well stocked with thrifty, growing timber which is largely Norway and jack pine, although other types are also represented. The Pike Bay Experimental Forest lies approximately six miles southeast of Cass Lake. It is predominantly an aspen-hardwood type, but includes a small area of virgin white and Norway pine.

The Kawishiwi Experimental Forest, comprising 2,635 acres, is about thirteen miles southeast of Ely, Minnesota, within the Superior National Forest. The three most important timber types on the Superior National Forest, and in the region immediately surrounding that forest, are represented within the experimental area. This portion of Minnesota is a distinct climatic region and the rock outcrop soil is unique in the Lake States. The result of studies made elsewhere in the Lake States Region can not be definitely applied to this large area of forest land and it is largely for the purpose of studying the proper methods of handling the jack pine, black spruce and aspen types that this experimental forest was established.

The federal forest research work in the Lake States Region is handled by the Lake States Forest Experiment Station which is maintained by the Federal Government in cooperation with the University of Minnesota at St. Paul. A branch station has been maintained for several years on the Chippewa National Forest. The designation of the Cutfoot and Pike Bay Experimental Forests will make it possible to concentrate the studies within the two areas, thus permitting a more efficient conduct of the studies and a more effective demonstration to the timberland owners in the vicinity who are interested in managing their own timber lands for the permanent production of timber. A branch station has also been established on the Superior National Forest and the designation of the Kawishiwi Experimental Forest is in furtherance of the research work at this branch station.

The Lake States Forest Experiment Station also maintains branch stations at Ruse, Michigan; Roscommon, Michigan (a fire studies station in cooperation with the State of Michigan); in Buffalo County, Wisconsin (for the study of erosion), and in North Dakota for the development of planting technique on the prairie regions of that state.

AWARDS OF THE AMERICAN MEDICAL ASSOCIATION FOR EXHIBITS AT THE NEW ORLEANS MEETING

CLASS I

AWARDS in Class I are made for exhibits of individual investigations, which are judged on the basis of originality and excellence of presentation. According to the report in the *Journal* of the American Medical Association they were:

The gold medal to Frank A. Hartman, C. W. Greene, J. J. Maisel and G. W. Thorn, University of Buffalo, for original investigative work on the development and use of a hormone from the suprarenal cortex and excellence of presentation.

The silver medal to C. W. Emmons, College of Physicians and Surgeons, Columbia University, New York, for original work on the variations in ringworm fungi and excellence of presentation.

The bronze medal to J. A. Bargen, P. W. Brown and H. M. Weber, Mayo Clinic and Mayo Foundation, Rochester, Minnesota, for original investigation of diseases of the colon and excellence of presentation.

Certificates of Merit, Class I, were awarded to the following:

To Abraham Levinson, Chicago, for exhibit illustrating continuation of investigations on the cerebrospinal fluid.

To Alton Ochsner, Earl Garside and Ambrose Storck, department of surgery, Tulane University Medical School, New Orleans, for exhibit illustrating the use of digestive ferments in prevention of adhesions.

To Sidney J. Wilson and Simeon H. Hulsey, Fort Worth, Texas, and Fred D. Weidman, Philadelphia, for exhibit illustrating excellent studies on chromoblastomycosis in Texas.

In addition, the following exhibit is deemed worthy of Honorable Mention:

That of John W. Towey, Powers, Michigan; Willis H. Huron, Iron Mountain, Michigan, and Henry C. Sweany, Chicago, for exhibit on occupational sensitization to fungus spores found in maple bark.

CLASS II

Awards in Class II are made for exhibits which do not exemplify purely experimental studies and which are judged on the basis of excellence of correlating facts and excellence of presentation. They were:

The gold medal to Max Ballin and Plinn F. Morse, Harper Hospital, Detroit, for excellence in presentation of exhibit on parathyroidism.

The silver medal to L. G. Rowntree and C. H. Greene, Mayo Clinic and Mayo Foundation, Rochester, Minnesota, for excellence of presentation of exhibit of comprehensive study on Addison's disease.

The bronze medal to Ernest Carroll Faust, department of tropical medicine, Tulane University Medical School, New Orleans, for excellence of presentation of exhibit on human helminth infections.

Certificates of Merit, Class II, were awarded to the following:

To Chevalier Jackson and Chevalier L. Jackson, Temple University School of Medicine, Philadelphia, for excellence of presentation of exhibit illustrating tumors of the lungs and tracheobronchial tree.

To Frank C. Neff, D. N. Medearis and Margaret Anderson, department of pediatrics, University of Kansas School of Medicine, Kansas City, for excellence of presentation of exhibit illustrating a study of the newly born.

To Henry F. Vaughan, Detroit Department of Health, Detroit, for excellence of presentation of exhibit illustrating plan of medical participation of the general practitioner in a public health program.

In addition, the following exhibits are deemed worthy of Honorable Mention:

That of Francis Clark Grant, University Hospital, Philadelphia, for excellence of demonstration of exhibit on ventriculography.

That of O. E. Denney, National Leprosarium, Carville, Louisiana, for exhibit on leprosy. (This work has been recognized by awards at previous scientific exhibits of the American Medical Association.)

The Committee on Awards commended especially the group exhibit of the Mayo Clinic and Mayo Foundation as a model of presentation, the excellent demonstrations given in the special exhibits on poliomyelitis, on cancer and on physical therapy.

A special Certificate of Merit was awarded to the American Society for the Control of Cancer for a co-operative exhibit on cancer as the best exhibit in the educational (national organizations) classification.

AWARDS TO ENGINEERS IN ENGLAND

IT is announced in *Nature* that the British engineering societies have made awards as follows:

The Council of the British Institution of Civil Engineers has made the following awards for papers read and discussed at the ordinary meetings during 1931–32: The Telford Gold Medals to Dr. C. F. Jenkin, emeritus professor of engineering science in the University of Oxford, and to Sir Bernard D'O. Darley, of Bahawalpur, India; the Stephenson Gold Medal to B. G. White, London; a Telford premium jointly to H. C. Whitehead, Birmingham, and F. R. O'Shaughnessy, Birmingham; Telford premiums to Raymond Carpmael, London, H. J. Deane, London, John Goodman, Skipton; a Manby premium jointly to W. F. Stanton, Bishops Castle, and A. G. Le Clercq, Walton-on-Thames; a Trevithick premium to W. C. Ash, Vizagapatam, India.

The Council of the British Institution of Electrical Engineers has made the following awards of premiums for papers read during the session 1931–32, or accepted for publication: Institution premium to J. Bruce; Ayrton premium to F. Lydall; Fahie premium to H. Kingsbury and R. A. Goodman; John Hopkinson premium to H. W. Clothier; Kelvin premium to Professor W. M. Thornton and Dr. W. G. Thompson; Paris premium to E. W. Dickinson and H. W. Grimmitt; extra premiums to H. Blades and A. C. MacQueen; R. O. Kapp and C. G. Carrothers; Dr. F. Luschen, H. Pearce and T. T. Evans; E. A. Watson, Major E. H. E. Woodward and W. A. Carne. Wireless section premiums: Duddell premium to T. L. Eckersley; extra premiums to B. S. Gossling, J. A. Ratcliffe, L. G. Vedy and A. F. Wilkins. Meter and Instrument Section premiums: Silvanus Thompson premium to Professor J. T. MacGregor-Morris and H. Wright; an extra premium to S. H. C. Morton.

Two awards of the Gold Medal of the Institution of Mining and Metallurgy, the highest distinction in its power to confer, have been made: (*a*) Sir Harold Carpenter, in recognition of his eminent services in the advancement of metallurgical science and technology; (*b*) Dr. Thomas A. Rickard, in recognition of his services in the general advancement of mining engineering, with special reference to his contributions to technical and historical literature. The following awards have also been made: The Consolidated Gold Fields of South Africa, Ltd., Gold Medal to P. J. Crowle for his investigations on ground movement and methods of support in deep mines, Kolar Gold Fields; The Consolidated Gold Fields of South Africa, Ltd., premium of forty guineas to Professor Bernard W. Holman for his work on flotation reagents; the William Frecheville Student's Prize of ten guineas to Gilbert F. Hatch for his paper on "Check Sampling of Diamond Drill Holes at the Trepca Mines, Jugoslavia."

SCIENTIFIC NOTES AND NEWS

THE Manson medal for tropical medical research, given triennially by the Royal Society of Tropical Medicine and Hygiene, has this year been awarded to Dr. Theobald Smith, who recently retired as director of the department of animal pathology of the Rockefeller Institute for Medical Research. The previous recipients of the Manson medal have been Sir David Bruce (1923), Senator Ettore Machiafava (1926) and Sir Ronald Ross (1929).

THE Lister Medal of the Royal College of Surgeons for distinguished contributions to surgical science has been awarded to Sir Charles Ballance, who will deliver the Lister Memorial Lecture at the college in 1933.

THE Hungarian Academy of Sciences has elected as foreign member Sir Arthur Eddington, Plumian professor of astronomy at the University of Cambridge and director of the Cambridge Observatory.

AT the annual convocation of McGill University on May 26, honorary degrees were conferred on Surgeon-General Robert Hugh Patterson, U. S. Army; Dr. Alfred North Whitehead, professor of philosophy at Harvard University, and Dr. J. S. Plaskett, director of the Dominion Astronomical Observatory.

THE presentation of the Mendel Medal will be made on June 7 at the commencement exercises of Villanova College to Francis P. Garvan, of New York, in recognition of his contributions to scientific progress. Former winners of the award have been Dr. John A. Kolmer, professor at the University of Pennsylvania; Dr. Albert F. Zahm, of the Congressional Library at Washington, and Dr. Karl F. Herzfeld, of the Johns Hopkins University.

PROFESSOR WILLIAM MUNDELL THORNTON, who holds the chair of electrical engineering at Armstrong College, Newcastle-on-Tyne, has been awarded the

Kelvin premium for 1932 in conjunction with Dr. W. G. Thompson for their paper on the absolute measurement of high electrical pressure.

HOWARD COLLEGE, Birmingham, Alabama, has conferred the degree of doctor of laws on Dr. A. Richard Bliss, Jr., chief of the division of pharmacology of the College of Medicine of the University of Tennessee.

DR. LEONARD THOMPSON TROLAND, director of research of the Technicolor Motion Picture Corporation, lecturer in psychology at Harvard University, died on May 27. He fell from a cliff, near the summit of Mount Wilson, California. Dr. Troland was forty-three years old.

DR. FRANCIS E. LLOYD, professor of botany of McGill University, has been elected president of the Royal Society of Canada in succession to Sir Robert Falconer, retiring president, of the University of Toronto.

PAUL J. SACHS, associate director of the Fogg Art Museum, was elected president of the American Association of Museums at the annual meeting of the association held in Cambridge from May 12 to 14. He succeeds Fiske Kimball, director of the Pennsylvania Museum of Art. Other new officers elected at the meeting were: *Vice-presidents,* Walter H. Siple, director of the Cincinnati Art Museum, and Hermon Carey Bumpus, trustee of the Children's Museum of Boston; *Secretary,* Alexander Wetmore, in charge of the U. S. National Museum. The following were re-elected: *Vice-presidents,* Arthur C. Parker, director of the Rochester Museum of Arts and Sciences, and Charles R. Richards, executive vice-president of the New York Museum of Science and Industry; *Treasurer,* George D. Pratt, trustee of the American Museum of Natural History and the Metropolitan Museum of Art.

DR. WILLIAM H. PARK was appointed at the recent New Orleans meeting to represent the American Medical Association on the council of the American Association for the Advancement of Science.

DR. ALLEN D. KELLER, professor of physiology and pharmacology in the University of Alabama School of Medicine, has been given a grant by the Committee on Scientific Research of the American Medical Association, to aid his investigations of brain-stem functions.

PROFESSOR CARLTON C. MURDOCK, assistant professor of physics at Cornell University, has been made a full professor.

THE following appointments to instructorships have been made in the School of Chemistry of the University of Minnesota for the coming academic year: in organic chemistry, Drs. P. D. Bartlett and C. F. Koelsch, now Research Council fellows at the Rockefeller Institute and at Harvard University, respectively; in chemical engineering, Fred Hovde, for the past three years Rhodes Scholar at the University of Oxford, and in analytical chemistry, E. B. Sandell, the present duPont Fellow at the University of Minnesota.

Nature states that at Jesus College, University of Cambridge, Dr. W. H. Thorpe has been elected a fellow. He has been a research fellow of the Rockefeller Foundation at the University of California and a member of the research staff of the Imperial Institute of Entomology. At St. John's College, Dr. L. Rosenhead has been elected a fellow. He entered the college with an open Strathcona Research Studentship for mathematics, and in 1930 was elected a senior research student of the Royal Exhibition of 1851.

DR. KARL M. DALLENBACH, who has been visiting professor of psychology at Columbia University for the past two years, returns to Cornell University next autumn as professor of psychology.

ACCORDING to a news dispatch E. H. Magoon, a sanitary engineer for the Rockefeller Foundation, arrived at Managua, Nicaragua, on May 26 to assist in the government campaign against malaria. A severe epidemic followed the earthquake last year, the mortality being very high, and the Nicaraguan Minister of Public Health requested aid of the Rockefeller Foundation.

C. M. HEH, head of the department of agronomy at the University of Nanking, China, has begun a year's study at Cornell University. At Nanking he has been associated with the Cornell-Nanking cooperative plant breeding project.

DR. LAFAYETTE B. MENDEL, Sterling professor of physiological chemistry in Yale University, delivered the annual Alpha Omega Alpha address in New Orleans on May 12. His subject was "Scientific Experiment and Medicine." Professor Mendel also addressed the students of the School of Medicine in Tulane University and at the Louisiana State Medical Center.

AT the annual initiation of the Cornell Chapter of the Society of Sigma Xi, which was held on the evening of May 19, 72 members and associates were admitted to the society. The annual address was delivered by Dr. Maurice C. Hall, chief of the Zoological Division of the Bureau of Animal Industry, Washington, D. C., on the subject "Playing the Scientific Game."

PROFESSOR HUGH STOTT TAYLOR, chairman of the department of chemistry, Princeton University, will deliver the Edgar Marburg Lecture at the annual meeting of the American Society for Testing Materials in Atlantic City in June. This lecture was established in 1926 as a means of emphasizing the importance of that phase of the work of the American Society of Testing Materials which deals with the promotion of knowledge of engineering materials. The lecture commemorates the name of the society's first secretary-treasurer, who, through his development of technical programs over a period of sixteen years, brought wide recognition to the society as a forum for the discussion of various aspects of materials used in engineering fields. The subject of the lecture is "Fundamentals in the Problem of Resistance to Deterioration."

SIR ARTHUR KEITH will deliver the Stephen Paget Memorial Lecture at the annual general meeting of the Research Defence Society to be held in London on June 15.

A LECTURE on the Liversidge Foundation will be delivered by Professor A. V. Hill, Foulerton research professor of the Royal Society, on May 13, on "Chemical Wave Transmission in Nerve."

THE fourteenth annual meeting of the American Society of Mammalogists was held at the United States National Museum, Washington, from May 3 to 7. There were 122 members present from 14 states and one Canadian province, this constituting the largest attendance at an annual meeting in the history of the society. Forty papers on various phases of mammalogy were presented. One resolution was adopted asking federal and territorial agencies for a more adequate protection of the brown and grizzly bears of Alaska, and another urging the U. S. Biological Survey to cease the poisoning of wild life. The officers elected were: *President,* Marcus W. Lyon, Jr.; *Vice-presidents,* H. E. Anthony, T. S. Palmer; *Recording secretary,* H. H. Lane; *Corresponding secretary,* Robert T. Hatt; *Treasurer,* Mrs. Viola S. Snyder; *Directors,* class of 1932–1934, W. K. Gregory, R. M. Anderson, Chas. C. Adams, H. H. T. Jackson, Lee R. Dice. Edward A. Preble continues as chairman of the editorial board in charge of *The Journal of Mammalogy.* The next annual meeting will be held at the Museum of Comparative Zoology, Cambridge, Massachusetts.

THE American Society of Clinical Pathologists held their eleventh annual convention in New Orleans, Louisiana, from May 6 to 9. Dr. W. M. Simpson was inducted into office as president for the year 1932–33, and Dr. A. G. Foord, of Pasadena, California, was the president-elect. The Ward Burdick Award was given to Dr. B. Kline, director of laboratories in Mt. Sinai Hospital, Cleveland, for his contribution on the serological diagnosis of syphilis. Dr. R. R. Kracke was given the gold medal award for his demonstration of agranulocytic angina at the scientific exhibit of the society. The society officially dedicated the department of pathology of the Louisiana State University on May 9.

DR. J. EDWARD HOFFMEISTER, secretary of the New York State Geological Association, writes that the eighth annual meeting of the association was held at the University of Rochester on May 13 and 14. It was attended by 175 people representing 15 institutions in the state. On the first day the group visited the Genesee Gorge, the Irondequoit Bay and the Pinnacle Hills in order to study the geology of the Rochester region. This was followed in the evening by a dinner and dance. A feature of the dinner was an address by Professor Herman LeRoy Fairchild, one of the original fellows of the Geological Society of America. On the following day a trip to the Devonian south of Rochester was made. This included stops at the High Banks of the Genesee River at Mt. Morris, and the Genesee Canyon in Letchworth Park near Portage. Next year the association plans to visit the New York City region. Professors R. J. Colony and Marshall Kay, of Columbia University, were chosen president and secretary, respectively.

THE summer meeting of the Corn Belt Section of the American Society of Agronomists and the American Society of Plant Physiologists will be held jointly at the University of Wisconsin, on July 11, 12 and 13. All agronomists and plant physiologists whether members of the societies or not are invited to attend. Headquarters will be in the new agronomy building, and the program will be built around the environmental relations of plants utilizing the significant examples of the work in progress in field, greenhouse and laboratory to illustrate principles and technique.

A GREAT part of the University of Valencia was destroyed by a fire of unknown origin which broke out on May 12 in the natural history department. Damage was done to the extent of several million pesetas, the astronomical observatory and the faculties of natural history, physics and chemistry, with their valuable collections and laboratories, being destroyed. Six people were injured, three of them students who, with their professors, were engaged in saving the most precious volumes of the library when a glass roof fell in.

THE new Oceanographic Laboratory of the University of Washington in Seattle will be dedicated on the afternoon of June 15, with Dr. Robert A. Millikan as the chief speaker. The laboratories are situated

on the shore of Lake Union at the foot of the campus, where ready access to the sea is obtained through the Lake Washington Ship Canal. The building is admirably equipped for research in oceanography, based on the fundamental sciences of physics, chemistry, botany and zoology. The Oceanographic Laboratories, besides the main laboratories to be dedicated in June, are composed of a research boat *Catalyst*, which is seventy-five feet long, Diesel driven, with a cruising radius of 2,000 miles, and the field laboratories at Friday Harbor in the San Juan Islands, comprising eight buildings of hollow tile construction, on 484 acres of land, with about two miles of shore line.

ACCORDING to the *Journal* of the American Medical Association ground was recently broken for the erection of a research laboratory at the plant of Merck and Company, Inc., Rahway. A south wing will be devoted to carrying on pure or fundamental research, for which three laboratories will be provided. Another laboratory will be fitted for biochemical research with an adjoining incubator room containing a sterilizer, incubator and other necessary equipment. In a pharmacologic laboratory the physiologic action of various chemicals will be investigated. There will also be a laboratory for micro-analysis, a microbalance room, an ordinary balance room and an ice room. The north wing will contain a large chemical laboratory suitable for twelve chemists carrying on applied research and development work. The central section will contain, among other things, a library.

ACCORDING to *The British Medical Journal*, an Alfred Fripp Memorial Fellowship, endowed with the sum of £7,000, has been established at Guy's Hospital for promoting the advancement of knowledge and research in psychology through the study of children in health and disease. The fellowship will be awarded by a board of electors consisting of the physician for diseases of children, the superintendent and the dean of the medical school as *ex-officio* members, and five others coopted by the *ex-officio* members. It will be open to either sex, but candidates must be unmarried, not more than 30 years of age, and be qualified to practice medicine or surgery; they will be expected to submit with their application a scheme of advanced study or research work. The appointment will be whole-time—it may be held concurrently with a demonstratorship—for a period of two years, which may be extended for a further period not exceeding three years at the discretion of the board of electors. The Fripp Fellow will be allowed opportunities for study in the children's department of the hospital, and the salary will be £300 per annum.

Nature reports that the amalgamation of the Optical Society and the Physical Society of London has been under consideration for some time. It has now been decided to proceed with the amalgamation. Certain alterations are to be made in the articles of association of the Physical Society, and, in due course, a general meeting of the Optical Society will be held to wind up the society.

DISCUSSION

LEIDY'S CRETACEOUS REPTILES OF THE UNITED STATES

IN Professor Henry Fairfield Osborn's interesting biography of Edward Drinker Cope, paleontologist, there appears on page 169 a severe criticism of Joseph Leidy's "Cretaceous Reptile Fossils of the United States, published under the auspices of the Smithsonian Institution," which Cope erroneously attributes to Professor Huxley, taken from the *Geological Magazine of London*, 1868.

The appended correspondence from the letter files of the Smithsonian Institution, contributed through George P. Merrill, geologist in charge, and the letter files of Professor Leidy's personal correspondence, should be preserved in the interest of the history of American science of that period and as a prelude to the *Elasmosaurus platyurus* episode, which is further elaborated on pp. 403–409 of the same biography. It is curious that Cope should have drifted into this error, as the work in question "was referred in 1865 by Secretary Baird of the Smithsonian Institute to Louis Agassiz and Edward D. Cope for review as to publication, both men naturally approved it" (see page 159), and, as Professor Osborn states, this memoir entitled "Cretaceous Reptiles of the United States" collected all the previous knowledge of American explorers, and put into the hands of Marsh and Cope all the knowledge of cretaceous reptiles up to that year, just as Leidy in his subsequent contributions of 1869 reviewed the entire western fossil mammalian life.

JOSEPH LEIDY, II

PHILADELPHIA

1302 Filbert Street,
Philadelphia, Pa.,
February 4, 1869.

COPY
P. S.
Dear Professor Henry:—

A very unfavorable criticism recently appeared in the London Geological Magazine on my last work on the

"Cretaceous Reptiles," published by the Smithsonian Institute. The review was signed by "H," which led others and myself, to suppose [that it] proceeded from Huxley, and I assure you I felt much annoyed about it, though I took no printed notice of it. I have just been informed by Professor Newberry of New York, that he was authorized to say that Professor Huxley not only did not write it but knew nothing of it until it was printed and that he does not sympathize with, but utterly condemns it. I give this information to you for I should not like my credit disputed.

Yours truly,
JOSEPH LEIDY.

School of Mines, Columbia College,
Corner 49th Street & 4th Ave.,
New York, Jan. 29th, 1869.

Professor Joseph Leidy
My dear Sir:—

I suppose you have noticed the very harsh and unjust review of your "Cretaceous Reptiles" in the October Number of Geological Magazine. I need not assure you that all who know you and the high character of all the scientific work you have done feel that American science which has no more creditable representative than yourself has been grossly insulted in the article referred to and that on this side of the Atlantic at least this review will do you more harm than good.

My object, however, in writing you now is not to tell you this, for you must know that such would be the feeling of your scientific friends, but to say to you that if you have been led to suppose from the fact that this review was signed "H" that it was written by Prof. Huxley, as was the impression producing great surprise and regret among us here when it was published, I can have the pleasure of assuring you that Professor Huxley did not write the article and knew nothing of it until it appeared and farther that he has no sympathy with the views or spirit of the article and condemns it as earnestly as we do. I have his authority for saying this much to you.

I suspect the avenues and the facts or assertions of the obnoxious article emanated from a source much nearer home.

We all deeply deplore Cassin's early death. At the last meeting of the Lyceum, resolutions of regret and sympathy were passed which will be communicated to his family.

I hope to be in Philadelphia in a few days and to see you. I have some things to say to you that I can't well put on paper.

Yours very cordially,
J. S. NEWBERRY.

SIGNIFICANCE OF BAER'S LAW

IN discussing my paper published in the issue of SCIENCE for November 13, 1931, Kirk Bryan and Shirley L. Mason[1] state that I "neglected to mention the factor of stream deflection due to the earth's rotation," in my explanation of contrasts, "in the rate at which denudation takes place on the banks of any rills or streams flowing in directions approaching east or west" in southern Ohio and in New Jersey. The impression which I get out of the discussion is that the authors consider that the neglect of this consideration may well invalidate all my observations.

The criticism of Bryan and Mason refutes itself: I called attention to the steepness of northward slopes in valleys having streams flowing east and in valleys having streams flowing west, mentioning both directions specifically. How then would right-hand deflection result in steepening of northward slopes? Their entire criticism breaks down before this one simple fact. It hardly seemed necessary to state that field observations yielded no hint of the influence of rotation on topography, nor to discuss that factor in a brief note on slope asymmetry. However, the point is discussed, and negatively dismissed, in one of the references I cited. F. Bascom[2] explains the steeper nothward slopes, characteristic of the Coastal Plain in New Jersey, on the basis of differential exposure which causes contrasts in the active processes of weathering and transportation.

Bryan and Mason cite the classic example of steep banks on the western sides of Long Island streams as evidence of the potency of rotation in producing asymmetric valley cross-sections. As Fuller[3] limits this characteristic to the portions of these valleys in outwash plains and definitely states that their cutting began in Wisconsin time it seems strange that Bryan and Mason shy away from the study of asymmetry in the glaciated portions of North America on the basis that many of the streams are "too youthful." Their statement that "Obviously the nearly unglaciated northern portion of Asia is the region for testing" the question of valley asymmetry appears inconsistent with their faith in the examples cited from Long Island.

The principle that rivers in the northern hemisphere tend to cut their right banks more vigorously than their left was apparently first advanced by Babinet,[4] though it is customarily called Baer's Law because of its formulation by Karl von Baer[5] in 1866. Dunker, Klockmann, Nansen, A. E. Nordenskiöld and others have discussed it at various times since. American geologists usually refer to the classic papers by Gil-

1 "Asymmetric Valleys and Climatic Boundaries," SCIENCE, 75: 215, 1932.
2 *U. S. Geol. Surv.*, Folio 167: 2, 1909.
3 M. L. Fuller, "Geology of Long Island," *Prof. Paper* 82: 51, 1914.
4 *Comptes Rendus Acad. Sci.*, xl: 638, 1849.
5 *Bul. Acad. Sci. Petersbourg*, 2: 1, 218, 353, 1866.

bert on the question. In recent years, Eakin[6] has concluded that it is operative for the lower 600 miles of the Yukon and that it influences the pattern of the Missouri River. The deflective force acting on any moving body varies with its mass, its velocity, and the sine of its geographic latitude. The factor of latitude is of such importance that the law has seldom been considered in explaining the courses of streams other than those in comparatively high latitudes. The factors mass and velocity are such that the possibility of an asymmetric effect appears to be reduced to insignificance in the case of smaller streams. Geologists are by no means united in an opinion that even under favorable conditions valleys, thalwegs, stream-threads, or stream patterns demonstrate unquestionably a morphologic effect of earth's rotation. Sir Archibald Geikie[7] states, "When, however, we consider the comparatively small volume, slow motion and continually meandering course of rivers, it may reasonably be doubted whether this *vera causa* can have had much effect generally in modifying the form of river-channels."

With but little effort an array of examples may be marshaled in support of Baer's Law, for example, those considered by Eakin, taken from the course of the Missouri River; or, equally convincing facts may be cited against it. The most rigorous test of the whole hypothesis, in all probability, has been that applied by Exner,[8] who finds that the swift-flowing, relatively large and well-established Danube at Vienna has about one one-thousandth more corrasive effect upon the right half of its bed than upon the left. In the light of Exner's rigorous computation of the deflective force acting on the Danube it seems utterly absurd to invoke the rotation of the earth as an explanation of conspicuous slope asymmetry in valleys of small streams and rills in southern Ohio and in New Jersey, apart from the fact that the phenomena cited in my paper are not limited to right banks.

In a series of observations on the geology and geomorphology of Louisiana now being undertaken by members of the school of geology at this university the thesis advanced in Baer's Law will be closely scrutinized. Though the latitude is somewhat less than that of southern Ohio and New Jersey, adequate compensation should exist in the slight degree of induration of the sediments being cut by streams flowing across the Coastal Plain.

RICHARD JOEL RUSSELL
LOUISIANA STATE UNIVERSITY

[6] H. M. Eakin, "The Influence of the Earth's Rotation upon the Lateral Erosion of Streams," *Jour. Geol.*, 18: 435–447, 1910.

[7] *Text-Book of Geology, London* (Macmillan and Company, 1: 23, 1903.

[8] Felix M. Exner, "Zur Wirkung der Erddrehung auf Flussläufe," *Geog. Annaler*, 9: 173–180, 1927.

LIGHT A FACTOR IN RANCIDITY[1]

RESULTS of experiments conducted in the Food Research Division of the Bureau of Chemistry and Soils show that certain wave-lengths of light play an important rôle in producing rancidity of oil-bearing foods.

Rice bran and rice polish were used in this investigation. When these products were kept under color filters such as blue, purple, blue-green, yellow and various shades of red, they showed characteristics of rancidity when examined organoleptically and by the modified Schiff's test. When kept under sextant green and sextant red filters, however, they showed no evidence of deterioration either by odor or in tests with the fuchsine sulphurous acid reagent. It is evident that the green filter, which approximates chlorophyll green, absorbs all photochemically active wave-lengths conducive to rancidity, allowing only chemically inert wave-lengths to pass through. The sextant red filter, being virtually black, accomplished the same result by absorbing practically all light. Screening out certain wave-lengths of light from oil-bearing foods and feeds, therefore, prevents or delays oxidation of the oil.

Antioxidants, such as pyrogallol, hydroquinone and substituted hydroxylamines, when added to oil-bearing foods may prevent or delay rancidity, but their use is considered objectionable on account of their possible physiological effects.

The keeping qualities of foods, such as salad oils, mayonnaise, butter, lard and potato chips, may be greatly enhanced by the use of properly colored wrappers, bottles, etc., capable of screening out active light wave-lengths.

A U. S. public service patent and foreign patents covering this discovery have been applied for. The application of the principle embodied in these patents should prove of great economic value to producers of package foods.

MAYNE R. COE
BUREAU OF CHEMISTRY AND SOILS,
U. S. DEPARTMENT OF AGRICULTURE

TWISTED TREE TRUNKS ON THE GASPÉ PENINSULA

IN connection with recent discussions in SCIENCE relative to the twisting of tree trunks during growth I should like to call attention to a forested area in Eastern Canada which should prove interesting to any one working on the growth of such trees. While encircling the Gaspé peninsula in the Province of Quebec over the new Perron Boulevard, we observed, among the logs which had been brought down from the mountain forests for pulp wood, a great many which were noticeably twisted, and where the more open agricultural land is divided by rail fences,

[1] Food Research Division Contribution No. 137.

twisted rails were very common; in fences four rails high, often one out of four and sometimes three out of four would be thus misshappen. As both pulp logs and rails were stripped of bark this twisting is very evident, especially with the latter when they are old and weathered.

The Gaspé is easy of access by auto from points in Maine and Quebec and with a guide familiar with the mountain forests this area would not be a difficult place to conduct investigations. A knowledge of French would be a desideratum, for, although the peninsula has been settled for some 300 years, practically all the population still speaks French only.

BEIRNE B. BRUES

SCIENTIFIC BOOKS

The Theory of Groups and Quantum Mechanics. By HERMANN WEYL. Translated from the second (revised) German edition by H. P. Robertson. New York, E. P. Dutton and Company. 422 pp. $6.00.

THE major importance of this authoritative work on group theory and quantum mechanics has become well known to theoretical physicists since the publication of the first German edition almost four years ago. Besides providing the most modern and stimulating account of the theory of groups as a branch of mathematical discipline, Weyl's latest book gives a masterly account of the applications to quantum mechanics. The first edition suffered from an extreme condensation which made it difficult to read. The second edition includes much new material corresponding to the advances particularly in quantum electrodynamics and in the theory of chemical valence. Moreover, the new edition is characterized by considerable improvement in clarity of presentation. This, together with the fact that the work is now available to American readers in an excellent translation, should give a great impetus to the assimilation of these ideas by American physicists.

Since the subject-matter of the book is quite abstruse, the reviewer feels that a technical criticism of its contents is of less value in a journal of general interests such as SCIENCE than a short essay on the general nature of group theory and its rôle in theoretical physics.

What, then, is group theory? A group consists of any set of elements in particular mathematical operations, which possesses a few simple properties. Each element of the group is an operation performed on some object. The single operation, which is equivalent in its effects to the successive performance of two operations of the group, is also counted as an element of the group. The inverse operation or operation that "undoes" the effect of any element of the group is further counted in the group. Two elements that "undo" each other in this way are called reciprocal elements. The identical operator, or the operation which leaves the object unaltered, also must occur in the group. The mode of combination of the elements must also obey the associative law, a simple general requirement which need not be stated explicitly.

It seems astonishing that the deductive method applied to such general postulates could produce a large body of theorems. But this is the fact, as mathematicians know. Of course, although they delight to express their results in the most abstract form possible, they know too that the group concept arose in a much more concrete way than the preceding paragraph would indicate. Perhaps the subject can be traced to Lagrange's (1770) recognition of the relation of the operations of permuting a series of objects to the theory of algebraic equations. But the real development of the subject with the same application in mind began a century ago (1831) in the researches of Galois. He introduced the term "group" in mathematics in the present technical sense of the word.

The details of the theory and the kind of applications depend much on whether the group contains a finite or an infinite number of elements and if infinite, whether the elements constitute a continuous or a discrete aggregate. In elementary geometry finite groups are of interest in studying regular solids: here each element of the group is the operation of rotating the solid through some particular angle about a particular axis so that the solid after rotation is indistinguishable from its aspect before the rotation. Thus a cube may be rotated through 120 degrees about a body diagonal without altering its geometrical relation to other objects. Closely related to this application to regular solids is the use of the theory of finite groups of rotations to describe and classify the various types of crystal symmetry. Considerations of this sort made possible a theoretical crystallography (Schoenflies, 1891) which has come very much to the foreground since Laue's discovery (1912) of the diffraction of x-rays, which provided a laboratory means for finding the arrangement of atoms in crystals.

The theory of infinite groups, especially of continuous groups, that is, groups each element of which is associated with a value or set of values of one or more continuous variables, finds application in the more advanced parts of geometry. The essence of a

system of geometry is contained in its means of characterizing the figures or designs that are counted as equivalent. Thus in ordinary geometry a circle and an ellipse are not counted as equivalent figures. But projective geometry counts as belonging to the same species any plane figure and the shadow cast by that figure when interposed between another plane and a point source of light. A circle may cast an elliptical shadow so an ellipse and a circle will be equivalent.[1] Other special systems of geometry are built on other relations of equivalence than that of the optical shadow just mentioned. But the general idea is much the same, as Klein first recognized in 1872 in his famous "Erlanger Programm." Here Klein first showed how the abstract theory of groups could serve as a unifying principle for the treatment of the numerous special advances in geometry made in the earlier part of the century.

This application of group theory to geometry brings us close to another leading concept which is of great importance to modern geometry and theoretical physics: the notion of invariance, and associated ideas like covariance. When a rigid body is displaced we say that its length is unaltered, that is, the length is unaltered or invariant under the operation of displacement. The group of all displacements includes any translation and any rotation. Length is an invariant of the group. When we say that length of an actual physical body is invariant we are making a physical assertion which may or may not be true of real bodies. But any way this may serve as an illustration of the concept of invariance.

Now it is fairly evident that such invariant quantities are the important elements in a physical theory, and thus we see how Klein's "Erlanger Programm" reaches over into physics: the physicist must learn to recognize the invariant elements in situations that confront him, and he must learn the nature of the group of operations under which that element is an invariant.

Klein himself recognized these things, and so we find that a set of his lectures delivered in 1915–1917 on the history of mathematics bears the subtitle, "Die Grundbegriffe der Invariantentheorie und ihr Eindringen in die mathematische Physik."[2] Aside from development of ordinary vector analysis and quaternions which are as much geometry as mathematical physics, the notion of invariant formulation of physical laws first found expression in the theory of relativity.

It is a triviality to say time is a fourth dimension in a world of space-time, if the statement carries no more content than that t is a fourth independent variable to go with x, y and z. What is the extra something which puts content into the concept of space-time? It is the specification of the group of transformations in space-time with which important physical invariants are associated. The crisis which resulted in the theory of relativity may be described thus: mechanics and electrodynamics each could be given invariant formulations, but the two branches of physics, while having common elements, seemed to be associated with different groups.

The group associated with classical mechanics is known as the Galilean group, while that of electrodynamics is the Lorentz group. Experiments like that of Michelson and Morley decided in favor of the Lorentz group as more fundamental for physics, so mechanics had to be altered to fit. In the Lorentz group, length of a rigid body is not an invariant, so the length appears different to different observers —the famous Lorentz-Fitzgerald contraction.

The general theory of relativity is simply a further development of the preceding ideas. For the examples thus far cited, the operations or transformations are linear in the coordinates of the points involved. Let them be general analytic transformations and let invariants of such an extended group be studied and the mathematical substratum of the general theory lies at hand. Of course to make a physical theory these mathematical results need coordination to the world with physical postulates, but the theory of groups provides the basis.

Now at last to quantum theory. In the examples heretofore cited, where the subject-matter is relatively less abstract, the development actually went ahead pretty much without the aid of the theory of groups. After it was completed the group theory provided the most systematic and unified standpoint from which to regard the results. But that was not the case with quantum mechanics. Here the applications of group methods (first by Wigner, then soon afterward by Heisenberg, von Neumann, Weyl and others) actually preceded development in other ways and first gave some of the most important new concrete results of quantum mechanics. The main applicability of group theory to quantum mechanics touches on two invariantive properties of the equations: An atomic system is invariant under ordinary rotations of the coordinate axes, hence the applicability of the continuous group of rotations as in geometrical problems; moreover, the different electrons in a many electron system are dynamically indistinguishable so the finite group whose elements are permutations of the electrons finds use here.

The theory of groups should be thought of as more than a tool for solving special problems, however,

[1] Actually the relation of projectivity is more general than that of perspectivity, but that does not alter the argument.

[2] Is it permissible to praise one book while reviewing another? This book of Klein's is delightful reading and the most valuable mathematical historical work that I have seen.

and it is in the connection now to be mentioned that the theory probably is most important for quantum theory and for theoretical physics in general. In spite of successes the present laws of quantum physics have their defects, and so it is necessary to find new and better ones. In the search for these, certain broad general requirements are laid down by the restrictions of invariance under different groups. The theoretical physicist need not waste time looking for laws outside the bounds thus set. More positively he finds on looking inside these bounds that the researches of pure mathematicians there have already provided a store of possibilities that await application to physics. This is the line of attack which will probably prove most fruitful in future modifications of the present quantum theory. It is for stimulation in this direction that a study of Weyl's book is perhaps most profitable.

To conclude, I can not refrain from giving wider circulation to an interesting historical point connected with the modern theories of chemical valence. In 1878, Sylvester, then professor of mathematics at Johns Hopkins, was worried about a lecture he had promised to give. He writes, "Casting about, as I lay awake in bed one night, to discover some means of conveying an intelligible conception of the objects of modern algebra to a mixed society . . . and impressed as I had long been with a feeling of affinity if not identity of object between the inquiry into compound radicals and the search for "Grundformen" or irreducible invariants, I was agreeably surprised to find, of a sudden, distinctly pictured on my mental retina a chemico-graphical image . . ." He then goes on to expound a very close analogy between his algebraic researches in invariants and the theory of chemical valence. He concludes with the sentence, "Thus we see that chemistry is the counterpart of a province of algebra as probably the whole universe of fact is, or must be, of the universe of thought."

This paper[3] does not seem to have attracted much attention: it was probably too mathematical for the chemists and too chemical for the mathematicians. It is mentioned, however, by Study,[4] in the Encyclopädie der Mathematischen Wissenschaften, who is somewhat inclined to sneer. "Formal analogies to the chemical structural formulas which occur in the theory of invariants of binary (and other) algebraic forms, have given rise to the fantastic hope," he writes, "that chemistry has something to gain from this branch of algebra. M. Noether has rightly, in a report on such attempts, pointed out the superficiality of the whole relationship and the lack of an actual analogy."

But the point of the story is that just exactly Sylvester's analogy and detailed calculations now play a rôle in quantum mechanical theories of valence, as Weyl has shown. The moral is obvious.

EDW. U. CONDON

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN INEXPENSIVE MICROGRAPHIC PROJECTOR

A PROJECTION and drawing apparatus which embodies many desirable features not found in commercial machines can be made after the design in Figs. 1, 2 and 3 accompanying this article.

An ordinary microscope is fastened to a vertical stand and inverted so that the light from a powerful lamp passes through the microscope projecting the image on a table to which the stand is attached.

The support is made of such material as is available to every laboratory. Ordinary ¾ inch galvanized pipes (B) are attached to a 47″ x 10″ x 1¼″ board by means of the collars (B′). The lamp is bolted to the wooden carrier (C) and the microscope is attached to a similar carrier (E) by means of a bolt and a strip of metal (D). Back and top views of a carrier are shown in Fig. 2, to show the location of the grooves which fit around the pipes (B). The carriers are held in place by tightening the bolts with wing nuts. The stand is held in a vertical position by the stove bolts (F) which hold it to the boards (H). These boards are fastened to the table by means of wood screws. The table top is made of white pine.

The microscope should be equipped with a substage condenser and interchangeable oculars of different magnifications. A loose ocular is held in place by inserting a very small piece of paper between it and the draw tube. A Bausch and Lomb light with a six-volt ribbon filament bulb gives very satisfactory illumination.

To operate the microscope and lamp, attach as illustrated. A slide is clamped on the microscope stage in the usual manner. A mechanical stage may be used to good advantage. Next the lamp is adjusted to obtain the maximum illumination. For low power work better illumination is secured when the substage condenser is removed. The image is brought into focus on a sheet of white paper on the table top. The size of the image may be regulated by changing the distance between the microscope (E) and the paper. To absorb the heat from the lamp a water

[3] Sylvester, "Mathematical Papers," 3, 148.
[4] Encylopädie, VI, 389.

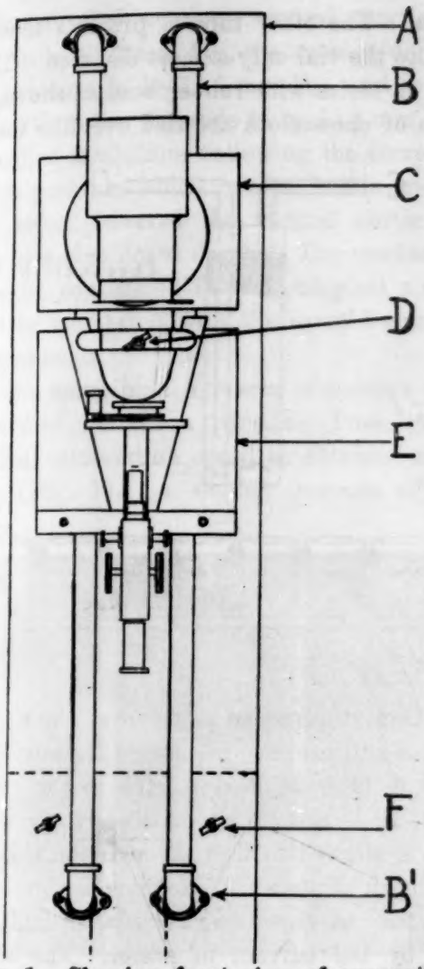

FIG. 1. Showing front view of apparatus.

bath may be interposed between the microscope and lamp.

In addition to projecting images from prepared slides, the apparatus offers numerous other applications. For example, material which must be maintained in a liquid may be placed on a slide or in a petri dish and set on the base of the microscope, after the substage condenser has been removed, and projected with the low power objective. The apparatus can be used to demonstrate to a small class the circulation of the blood in a frog's foot. It can also be made to serve for short distance projection. To accomplish this, the wing nuts (F) are removed and the apparatus is placed on the table in a horizontal position. A camera may be fitted to the microscope for taking photomicrographs.

To my knowledge no commercial drawing apparatus is equipped for projection of large transparent objects, such as long insect wings. To adjust the apparatus for large field projection the same stand as shown in Fig. 3 is used, but a large lens (I) and a portrait lens (J) are substituted for the microscope (E). An image of the object, which is placed on the flat surface of the lens (I), is projected through the lens (J) to the table. The support illustrated was

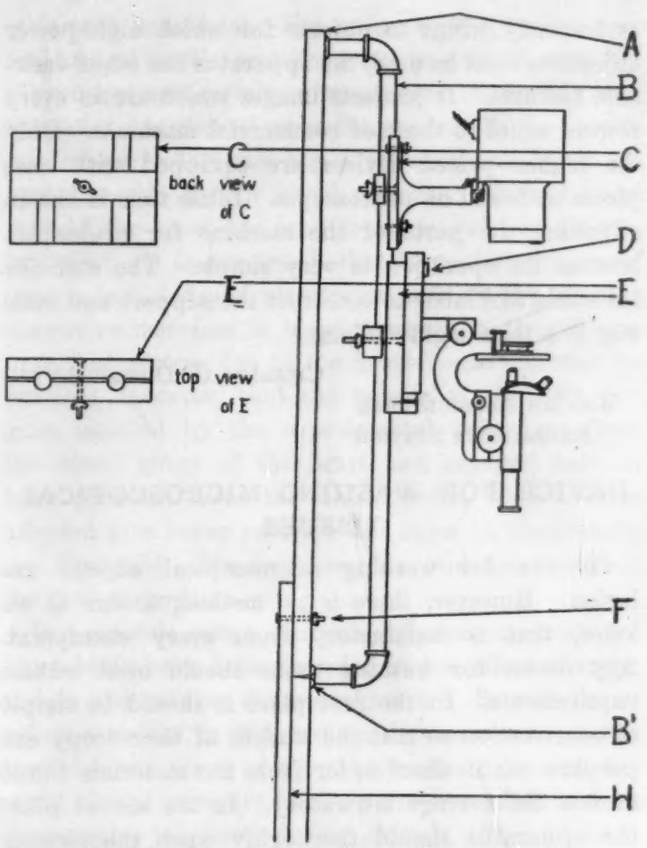

FIG. 2. Showing side view of apparatus.

made to accommodate the lens equipment of an old Leitz photomicrographic machine. For the lens (J) a 72 mm Bausch and Lomb-Zeiss Tessar lens as well as other close-range camera lenses were found to give good results.

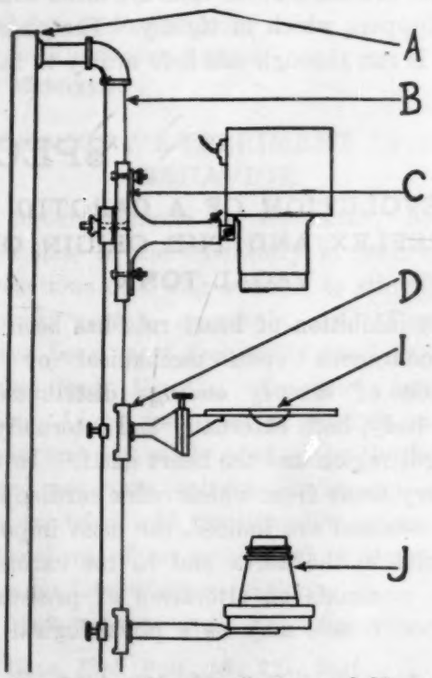

FIG. 3. Showing equipment for large field projection.

In addition to the distinct advantage of projecting images of objects ranging in size from those as large

as butterfly wings to objects for which high power objectives must be used, the apparatus has other desirable features. It projects images which are in every respect equal to those of commercial machines. Only the higher priced devices are equipped with nose pieces as found on microscopes. Little time is lost in adjusting the parts of the machine for projection, because its operation is very simple. The cost for materials and labor to construct the support and table was less than eight dollars.

CHARLES G. DOBROVOLNY
KANSAS AGRICULTURAL EXPERIMENT STATION

DEVICE FOR WASHING MICROSCOPICAL TISSUES

DEVICES for washing microscopical objects are legion. However, there is no method, so far as we know, that is satisfactory from every standpoint. Any device for washing tissue should meet certain requirements. In the first place it should be simple of construction so that the student of microscopy can prepare one in short order from the materials found around the average laboratory. In the second place the apparatus should thoroughly wash the objects, subjecting them to a constant stream of fresh water.

The following method is convenient to construct and has certain other advantages. A wooden block about 12 inches by 6 inches by 1 inch is provided with holes 1 inch in diameter and about $\frac{3}{4}$ inch deep, spaced at intervals of about $1\frac{1}{2}$ inches, in which vials $\frac{7}{8}$ inch in diameter are set. These vials are fitted with 2-holed rubber stoppers which fit tightly. The glass tube D (Fig. 1) is run through one hole nearly to the bottom of the vial. The other tube C projects through the stopper into the vial only a short distance. These are connected in series with rubber hose as shown in Fig. 2. Pieces of cheesecloth are tied over the inner ends

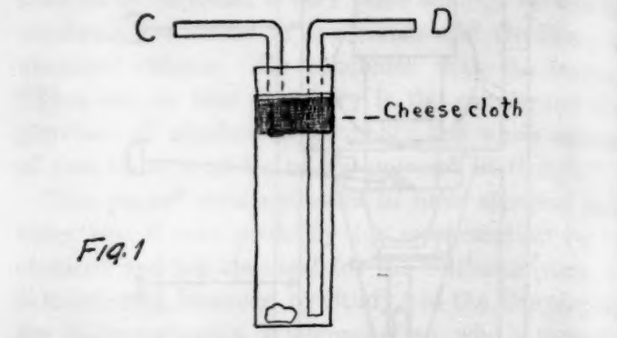

Fig. 1

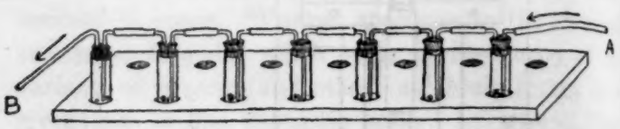

Fig. 2

of the rubber stoppers so as to cover the ends of the outlet tubes and prevent the objects from washing out. The hose A (Fig 2) is connected to the spigot and the other, B, is the outlet. A steady, gentle stream of water is allowed to flow through the vials for the desired length of time. This device insures thorough washing, for the objects are constantly agitated and revolved by the current of water. The whole apparatus may be placed out of the way at one side of the sink. A varying number of vials may be used according to needs.

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SPECIAL ARTICLES

THE EVOLUTION OF A CAROTID SINUS REFLEX AND THE ORIGIN OF VAGAL TONE

REFLEX inhibition of heart rate has been observed in elasmobranchs upon mechanical or electrical stimulation of sensory endings distributed widely over the body, both externally and internally, including the gill region and the heart itself.[1] In mammals the sensory areas from which reflex cardiac inhibition may be obtained are limited, the most important being located in the aorta and in the carotid sinus.[2] Since in mammals an alteration of pressure within these blood vessels may be a physiological stimulus, the writers tried the effect of alterations of pressure within the branchial vessels of elasmobranchs.[3]

The ventral aorta of *Squalus acanthias*, with the cord destroyed, was ligated between the first and second branches and a cannula connecting with a burette, containing a physiological solution, was inserted anterior to the ligature. Cardiac inhibition was obtained when the pressure within the gill vessels was suddenly increased. A series of threshold determinations showed that an average increase of 10.7 mm Hg above the average systolic pressure in the dorsal aorta was found to constitute an effective stimulus for the inhibitory response. The response was found to be reflex, with afferent pathways located in the branchial nerves and efferent fibers in the vagus supply to the heart. Determinations of the blood pres-

[1] B. R. Lutz, *Biol. Bull.*, 59: 170, 1930.

[2] J. A. E. Eyster and D. R. Hooker, *Am. Jour. Physiol.*, 21: 373, 1908; G. V. Anrep and H. N. Segall, *Jour. Physiol.*, 61: 215, 1926; C. Heymans, "Le sinus carotidien," Louvain and Paris, 1929.

[3] B. R. Lutz and L. C. Wyman, *Biol. Bull.*, 62: 10, 1932.

sure showed the average ventral aortic systolic pressure to be 28.2 mm Hg, the average dorsal aortic systolic pressure to be 15.4 mm Hg, and the average ventral aortic pulse pressure to be 13.3 mm Hg. The reflex cardiac inhibition, following the increased ventral aortic pressure which results from a spontaneous ejection reflex, lowered the ventral aortic diastolic pressure to a significant degree. The mechanism may therefore be considered of physiological significance and may be compared with the carotid sinus mechanism of mammals.

When the amphibian *Necturus maculosus* was used, reflex cardiac inhibition resulting from mechanical or electrical stimulation could be obtained only from the gills (Fig. 1). A sudden increase of vascular

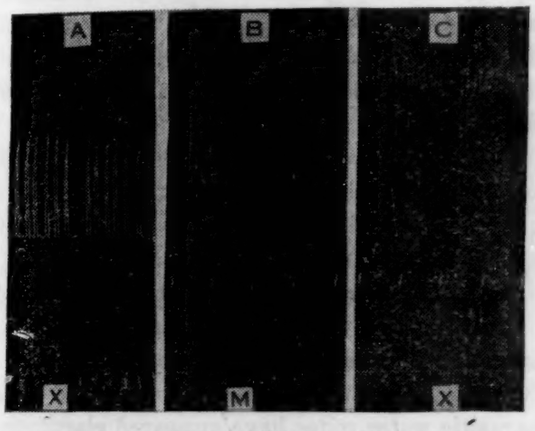

FIG. 1. Reflex cardiac inhibition. Heart beat recorded by lever. Time, five-second intervals. A. *Squalus acanthias*. Cord destroyed. Increase of pressure, at X, to 44 mm. Hg in the first branches of the ventral aorta. B. *Necturus maculosus*. Cord destroyed. Mechanical stimulation of left gills at M. C. *Necturus*. Decerebrated. Increase of pressure, at X, to 49 mm Hg in the ventral aorta.

pressure within the gill vessels also evoked reflex cardiac inhibition, even when the burette pressure was as low as 34 mm Hg.

It is conceivable, therefore, that in the course of evolution the wide-spread sensory areas of the ancestral form, possibly typified by the elasmobranch, with *Necturus* as an intermediate type, were concentrated or restricted until the condition seen in the mammal was reached. Since the carotid arteries of the mammal are derivatives of the primitive branchial system, the reflex cardiac inhibition of branchiovascular origin may exemplify the evolutionary forerunner of the carotid sinus reflex in mammals.

Inasmuch as the threshold for this reflex in *Squalus acanthias* was found to average 10.7 mm Hg above the dorsal aortic systolic pressure, and the average ventral aortic pulse pressure was found to be 13.3 mm Hg it follows that inhibition may occur with each heart beat. For example, in a typical case the ventral aortic systolic pressure was 22 mm Hg, the ventral aortic pulse pressure was 16 mm Hg, and the reflex was elicited when the pressure in the burette was raised to 18.6 mm Hg, a pressure well below the ventral aortic systolic blood pressure. Marked vagal tone of the heart has been found to exist in elasmobranchs.[4] It is suggested, therefore, that this vagal tone is initiated and maintained reflexly through the successive increases in blood pressure in the afferent branchial system due to the heart beats. It may be possible, however, that the vessels of the first two gills, isolated by the experimental procedure from the direct effect of the heart and exposed only to back pressure from the dorsal aorta, have become adapted to a lower pressure and show an abnormally low threshold. We have seen no evidence, however, for this supposition.

In mammals action currents synchronous with the heart beats have been recorded in the afferent vagus and in the cardiac depressor nerve.[5] Bronk[6] found action currents in the cardiac depressor and in the carotid sinus nerve of the rabbit coincident with the rapid rise of pressure in the pulse wave followed by comparative inactivity during diastole. This evidence and that obtained from the dogfish point to a special function of these afferent nerves, stimulated by the systolic pulse, in connection with the reflex origin of vagal tone. The phylogeny of a special physiological process in mammals is thus indicated.

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A LABORATORY EXPERIMENT IN ANIMAL BEHAVIOR

MOST modern courses in elementary biology or zoology include in the laboratory at least one exercise on reactions of living animals to stimuli such as light, gravity, touch, chemicals, etc. The animals which have been most frequently used in our own laboratories are Eisenia, Tenebrio larvae and Drosophila. Light responses of Eisenia and Tenebrio larvae are not easily studied in the laboratory which does not have suitable darkrooms available. This year we tried with considerable success a study of the responses of an animal which reacts readily to light under laboratory conditions.

Many fresh-water mussels are infested with para-

[4] B. R. Lutz, *Biol. Bull.*, 59: 211, 1930.

[5] W. Einthoven, *Quart. Jour. Exp. Physiol.*, 1: 243, 1908; E. D. Adrian, *Jour. Physiol.*, 61: 49, 1926.

[6] D. W. Bronk, *Proc. Soc. Exp. Biol. Med.*, 28: 1014, 1931.

sitic water mites which live between the gills. One of the common species of the eastern United States, *Unionicola ypsilophorus* var. *haldemani* (Piers), is found in *Anodonta cataracta* Say. This mite occurs abundantly, at least in eastern Massachusetts, and can be obtained at any time of year when the host is available. When these animals are removed from the host, washed and placed in water free from host material, they show a positive response to light. If water from the mantle cavity, or water extract of the gills is added to water containing the mites, they usually show a distinct reversal to a negative state as regards the light. This negative response may persist for a half hour or more if the concentration of host material is high. The reversal may be interpreted as a type of conditioned response brought about by some material from the host; the positive response to light being primitive and the negative response acquired since the mites have taken up a parasitic life. It may also be shown in the case of *Unionicola* from *Anodonta* that only material from the host will bring about a reversal, water from the mantle cavity or extract of the gills of such forms as *Elliptio* or *Lampsilis* having no effect on the mites. The influence of host on parasite is seen therefore to be specific for a particular host-parasite combination.

In a typical experiment ten mites are placed in a small rectangular glass jar with sufficient water to cover them. This is placed between two light sources which may be used alternately. In a series of trials, using first one light source and then the other, the number of mites which are positive may be determined and any which are negative may be removed if desired. If one light source is of high intensity (100 watt lamp) and one of low (15–25 watt lamp) they may both be used at the same time and the effect of intensity on the behavior of the mites observed.

Next, using one light source and attracting the animals to the end of the jar toward the light, a small amount (1–3 cc) of filtered extract of gill may be added in the neighborhood of the mites, and usually there is an immediate reversal to a negative state. This is not a chemotropic response, for the mites will often move out of the region of greatest concentration of extract to a region of lower concentration. If results are not conclusive the mites may be washed, returned to fresh water, and the experiment repeated.

Finally, if desired, the mites may be allowed to collect on a small piece of gill and usually, regardless of directional illumination, they will remain on the piece of gill probably as the result of a positive stereotropic response to a familiar surface.

Not all species of mites are satisfactory for such experiments. Some have been parasites for so long that they have lost almost all power of locomotion, others, such as *Unionicola fossulata* (Koen) from *Cyclonais tuberculata*, are positive only to light of low intensity (about 0.1 meter candles) a condition difficult to attain outside the darkroom.

Two papers by the author regarding the behavior of parasitic water mites have appeared elsewhere.[1]

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Experiments on the nature of the structural units of solids: ALEXANDER GOETZ (by invitation). It is necessary for a general understanding of the physical properties of crystalline solids to assume in addition to a regular geometric configuration of atoms or molecules in a crystal lattice also the existence of a mosaic structure, as has been proposed in recent years by Smekal, Ewald, Darwin and Zwicky mostly with regard to heteropolar substances. Because of the special interest of the effects depending on the mosaic structure in metals, *i.e.*, homopolar lattices, a systematic experimental investigation has been started which, up to the present, leads to the following general conclusion: A crystal consists of a more or less regular conglomerate of structural units, the size of which is a quality of the substance in question. Each unit is an ideal crystal in itself, its boundaries which coincide with certain low index planes form potential walls, which as such affect the electric transparency of the crystal. Impurities of structurally different substances are imbedded within the boundaries affecting their separating qualities and being sometimes even able to start new types of boundary-layers along different crystallographic planes. At higher temperatures the perturbing influence of these boundaries affects the structural unit to a larger extent and thus decreases the size of the ideal structural unit without affecting their number. Hence a block of metal in its most stable, *i.e.*, single crystalline configuration is considered as consisting of a crystalline and an amorphous component.

Supra-conductivity and the Hall effect: EDWIN H. HALL. Kamerlingh Onnes described two experimental investigations, each of which he regarded as indicating that there is no Hall effect in the supra-conductive state of a metal. In the first of these, plates of tin and of lead, respectively, in the supra-conductive state were tested directly for a Hall effect in the usual way, between the poles of a magnet. In the second, a spherical

[1] "Reversal of Phototropism in a Parasitic Water Mite," *Biol. Bull.* 59, 165, 1930; "Specific Influence of the Host on the Light Responses of Parasitic Water Mites," *Biol. Bull.*, 61, 497, 1931.

shell of lead, in which self-persistent electric currents had been induced, was suspended in a magnetic field under such conditions that a torque exerted by the twisted suspension was opposed by a torque exerted on the current-bearing sphere by the magnetic field. When a balance between these torques was once established it remained substantially unaffected for hours. Onnes interpreted this fact as proving that the persistent currents in or on the surface of the sphere were held unchanged in their paths in spite of the couple exerted upon them by the magnetic field in which the sphere was suspended, and this conclusion he expressed by saying that there was no Hall effect in the supra-conductive lead. The first of these two methods of experimentation seems open to the objection that the lines of induction of an applied magnetic field can not penetrate a metal which is already in the supra-connective state. Criticism of the second method can not be so briefly stated. The question whether a metal in the supra-conductive state can show a Hall effect remains undecided. The proper way to answer this question would seem to be as follows: Apply the magnetic field to the metal plate, carrying a longitudinal current, while the metal is in the normal state, then cool it to the supra-conductive state, test for a transverse potential difference, then raise the temperature of the metal above the transition point, reverse the magnetic field, cool to the supra-conductive state again, then test for a transverse potential difference opposite to the one observed before.

The scattering of light by supersonic waves: P. DEBYE and F. SEARS.

The projection of motion pictures in relief: an experimental realization: HERBERT E. IVES (introduced by F. B. Jewett). The projection of motion pictures in relief, visible to a group of observers occupying a wide range of positions with respect to the screen, but demanding no special spectacles or other apparatus at the eyes, has been experimentally realized on a small and crude scale by an application of the principle of the parallax panoramagram. The individual pictures constituting the record of motion and relief are made up of narrow juxtaposed strip images, each of which is a minute linear panorama of the scene presented to the camera. The camera consists of a large 4-foot diameter concave mirror, at whose focus is a transparent screen consisting of approximately 200 minute concave grooves. The virtual images of the mirror formed in these grooves are photographed by a single exposure onto a lantern slide size plate. Prints from negatives so made are then mounted on a large disc capable of slow rotation in the slide plane of a projection lantern coupled with another rapidly rotating disc with an aperture which flashes a bright beam of light through the projection system as each picture comes into position (Plateau's magic disc or Plenakistoscope). The projection screen consists of 200 transparent rods, one quarter inch in width, having convex cylindrical surfaces in front and rear, of such curvatures that linear images on the rear surfaces are projected as parallel beams into the observing space. When the pictures, made as above described, are projected with each panoramic strip in accurate register upon a rod a composite picture is seen on the 4-foot diameter screen which varies with the direction and distance of observation, exhibiting stereoscopic relief. Succession of such pictures at the rate of 15 to 20 per second provides motion pictures in relief. Successful results depend upon such extreme accuracy of all mechanical and optical parts and adjustments that commercial application appears remote.

Some recent developments of electric waves guided by wires: GEORGE O. SQUIER. There is no depression in science, but on the contrary it has been said that we are in the midst of a second and greater Renaissance. During 1931 the Bell Laboratories have concentrated on the investigation of wide-frequency band transmission of electric waves over telephone cable circuits, the results of which are summarized as follows: It now seems clear that circuits can be provided in aerial or underground cable that will have characteristics permitting an extremely wide band of frequencies to be transmitted with substantial uniformity throughout the band. The net result of this work has been to open up the possibility of very long circuits, each of which can carry a very large number of non-interfering telephone communications, and a very much larger number of non-interfering telegraph communications. Television, which is still "around the corner," logically fits into the spectrum of short electric waves guided by wires. The year 1931 has witnessed no "depression" in the development of broadcasting. Instead the thoughts of the whole world were delivered by engineering skill from any quarter to the very walls of the steel frameworks of the huge buildings which house our city populations. This "Outdoor Broadcasting" has been accomplished, but we must now attack seriously the engineering problem of "Indoor Broadcasting" by which these myriad messages may be sorted out and delivered to the vast audiences within these steel walls who are the "supreme court" of ultimate success. The next two years will witness this basic engineering problem being realized by going directly back to the original plans of Marconi. Instead of broadcasting through space for hundreds of miles from an antenna, we will set up a complete radio broadcasting plant inside a multiple wire cable and broadcast multiple programs from a single antenna within the cable to receivers in each of the rooms. This is the only engineering solution of interference prevention to meet the severe requirements of each and every tenant who has chosen to live inside these modern steel structures. There are two methods of accomplishing this, to wit: (1) Utilize the existing telephone plant already provided. (2) Construct a separate wire-wireless indoor broadcasting equipment. Radio City offers an ideal opportunity for this development.

Evidences of cycles in tree ring records (illustrated): A. E. DOUGLAS (by invitation).

Periodicities in solar variation: C. G. ABBOT. Summary was made of the observations of the Smithsonian Astrophysical Observatory since 1895, including references to various new instruments for scientific work. Among them is the periodometer which has been employed to discover and evaluate periodicities in solar variation and in the temperatures of Clanton, Alabama, Washington, D. C., and Williston, North Dakota. The variation of the sun since 1918 is well represented as the sum of 7 periodicities, respectively of 7, 8, 11, 21, 25, 45 and 68 months. The temperature departures of the 3 stations named are also closely represented as the sum of these periodicities supplemented by two or three others which seem to be of terrestrial rather than of solar origin. However, at each station the sum of the amplitudes of the periodicities apparently of solar origin exceeds by about twofold the sum of the amplitudes of the terrestrial periodicities. This indicates that temperature departures are largely governed by variations of the sun, and holds out a hope of long period forecasts possibly extending for several years in advance. Further investigation must ensue before this hope can be thoroughly tested.

The nature of the solar cycle: W. S. ADAMS and S. B. NICHOLSON. The physical appearance of the sun varies from day to day as the sunspots, faculae and prominences develop and disappear on its surface. These phenomena may be distributed irregularly around the sun so that the number of objects visible at any time depends on the rotation period of the sun which approximates to a month. Their average monthly frequency, therefore, is an indication of the actual solar activity. The solar activity measured by this method fluctuates irregularly in cycles ranging from six to fifteen months and shows variations up to one fourth its mean value. The solar cycle which is most nearly periodic and which has the largest amplitude is of about eleven years' duration. This period may vary between nine and fourteen years and the amplitude of the cycle by about 50 per cent. of its average value. Period and amplitude are apparently unrelated. It seems probable that both the quantity and quality of solar radiation vary during this cycle and many attempts have been made to correlate terrestrial phenomena with sun-spots. Definite correlations have been found with the variations of terrestrial magnetism and its related phenomena. There is evidence of a slight correlation between sun-spots and atmospheric temperature in certain regions on the earth and with other factors of weather and climate for limited regions and for limited time intervals. These correlations are so uncertain that, in the majority of cases at least, predictions based on them have very little weight.

Correlation of sedimentary and climatic records: ISAIAH BOWMAN. The earliest studies of banded sediments were made to obtain measures of geologic time—measures akin to those of Michelson on the speed of light in that the end in view was a more accurate yardstick. Later on, the interpretation of sediments passed into a more advanced stage in which there was accomplished the cross-dating of banded clays of late glacial origin. The most noteworthy work upon them was done by De Geer in Sweden and by Antevs in New England. The latter demonstrated a rate of retreat of the ice in the Connecticut Valley of about a mile in twenty-two years over a period several thousands of years long. By comparing the lake deposits in series along the edge of the ice front the measured rate of retreat of the ice was determined. But up to the present all such datings are relative. That is to say, no one has yet found the bottom of the oldest deposit nor the top of the youngest. Nor has there been established a correlation between the banded clays of New England and the oldest trees. The clays are on one side of the country and the oldest trees, the Sequoias, are on the opposite side and the differences in climatic habit are wide. Because the lakes of the Great Basin have expanded and contracted in response to climatic change, one naturally turns to that region for a possible correlation between lake history and tree history to see if identical periods of wetness and dryness can be distinguished. Unfortunately, from this standpoint, the lakes of the Great Basin are and have been mostly salt lakes, whereas the banded clays that lend themselves most readily to the dating of events in geological time are formed in fresh-water lakes. A neglected field of study has been the sedimentation process. Until that process is studied in detail and correlated with rainfall, temperature, cloudiness and stream discharge, there is no solid experimental basis for the interpretation of sediments now exposed on basin floors in sections that are accessible. The drought of the past three years has exposed lake floors that have been covered with water for many decades and that have been exposed to view probably not more than once or twice since white occupation of the West. This makes it a matter of urgent importance that the studies of the now dry lake beds should be pushed with all speed before they again become covered with water and the sedimentary record of their fluctuations is again difficult to sample.

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